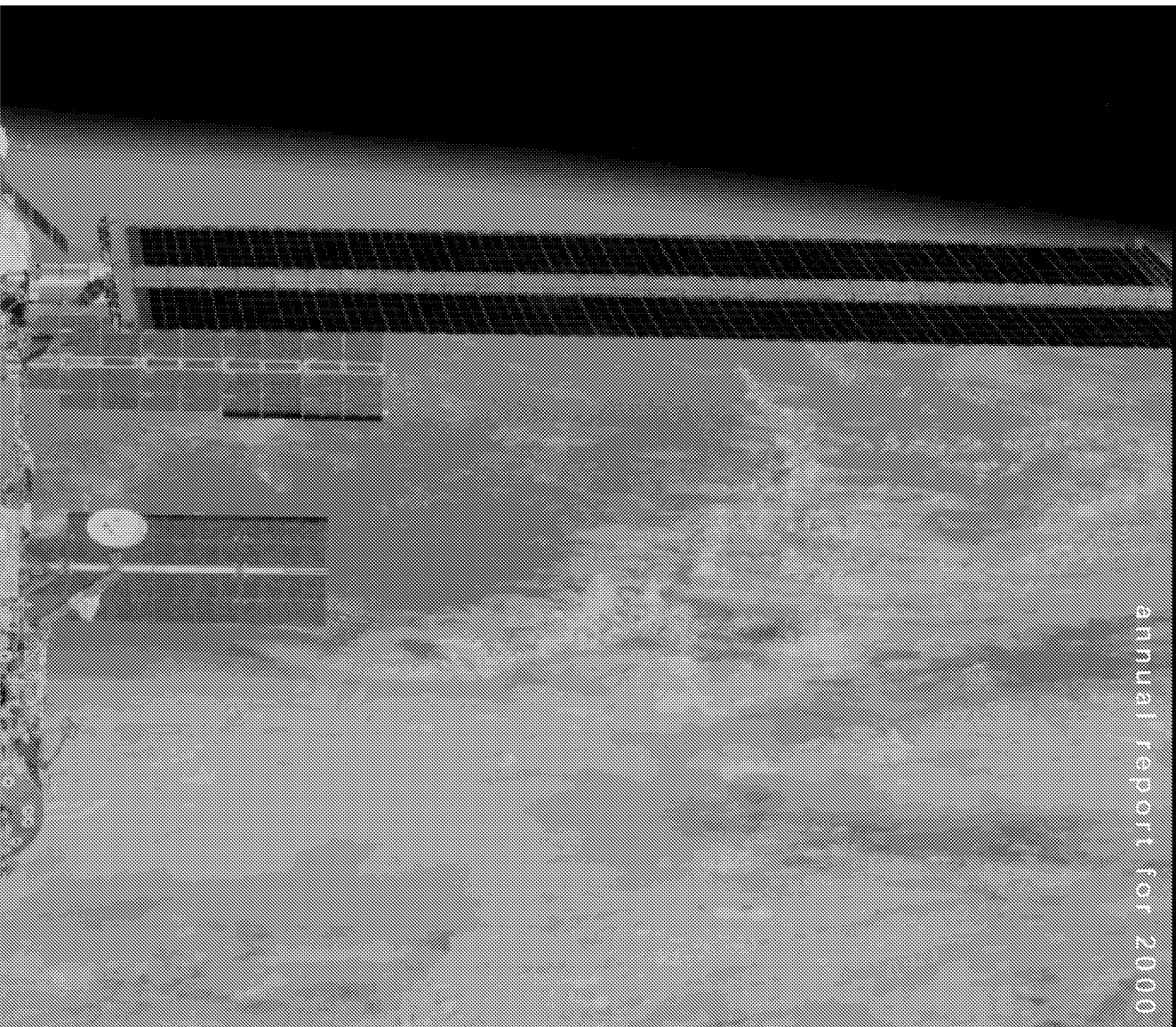


# aerospace safety advisory panel

annual report for 2000



"The Panel shall review safety studies and operations plans referred to it and shall make reports thereon, shall advise the Administrator with respect to the hazards of proposed operations and with respect to the adequacy of proposed or existing safety standards, and shall perform such other duties as the Administrator may request."

NASA Authorization Act of 1968 | Public Law 90-67, 42 U.S.C. 2477

National Aeronautics and  
Space Administration

**Headquarters**  
Washington, DC 20546-0001



February 2001

Q-1

Honorable Daniel S. Goldin  
Administrator  
National Aeronautics and Space Administration  
Washington, DC 20546

Dear Mr. Goldin:

The Aerospace Safety Advisory Panel is pleased to submit its Annual Report covering calendar year 2000. This was a year in which the assembly and habitation of the International Space Station (ISS) moved ahead with vigor. The Space Shuttle and ISS programs achieved significant milestones as they worked together to turn years of space station planning into a functioning human orbital outpost.

The success of the initial ISS assembly efforts leads to the expectation of many years of productive operations. We do not yet see, however, plans and resource commitments that are commensurate with the continued safe operation of the Space Shuttle over the full productive life of the ISS. The overarching theme of this year's report is, therefore, the need for NASA, the Administration, and the Congress to define and commit to a realistic projection of Space Shuttle service life. This theme is developed more fully in the introduction of the report.

At present, safety is being well served by both NASA and its contractors. The past year provided several laudable examples of decisions that clearly placed safety ahead of schedule and cost. There was also a promising initiative to begin rebuilding critical skills.

Once again this year, the Panel is appreciative of the excellent cooperation from NASA and contractor management and operating personnel that facilitated our task.

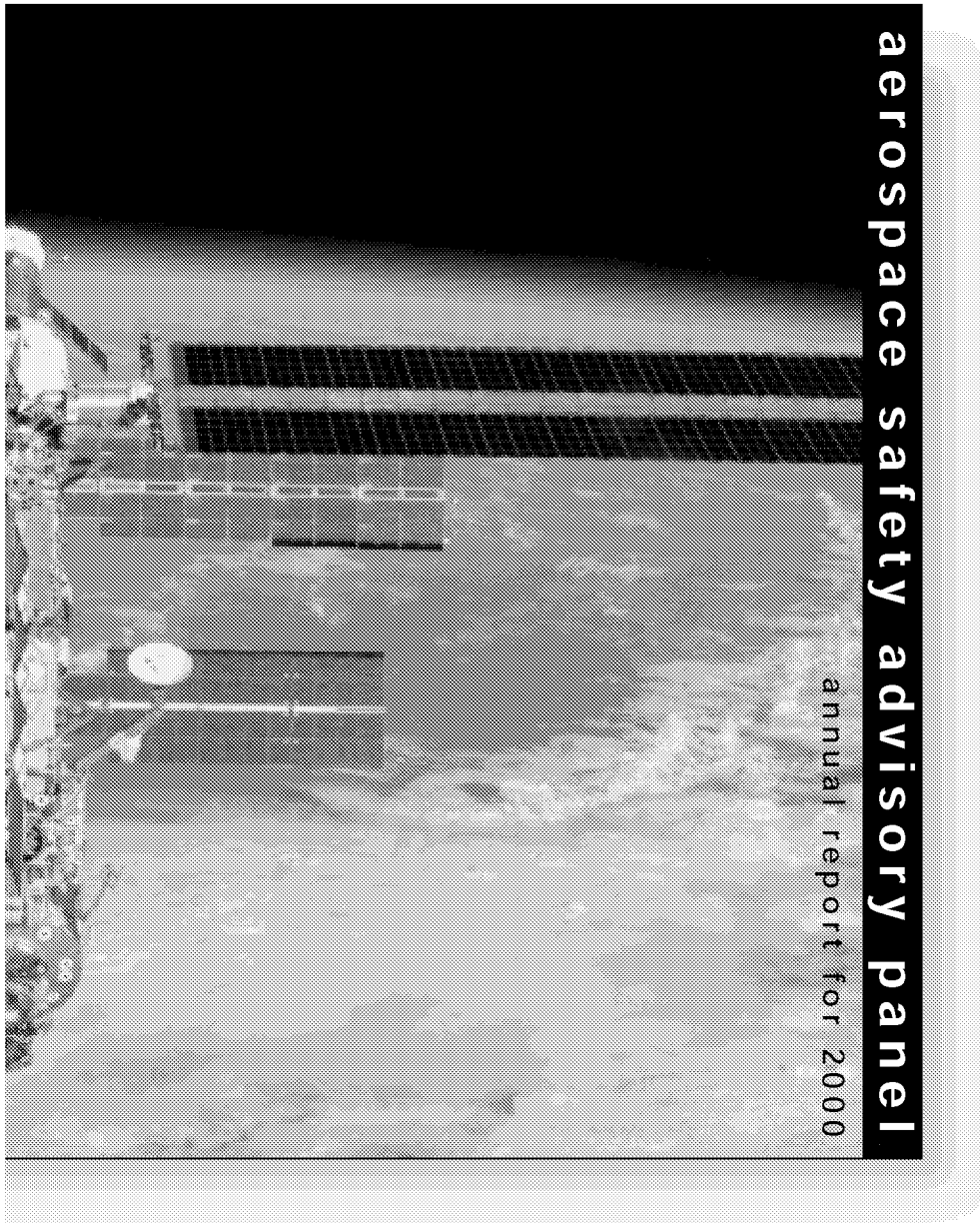
Sincerely,

A handwritten signature in cursive script that reads "Richard D. Blomberg".

Richard D. Blomberg  
Chair  
Aerospace Safety Advisory Panel



National Aeronautics and  
Space Administration



**Aerospace Safety Advisory Panel**

Code Q-1 | NASA Headquarters | Washington, DC 20546

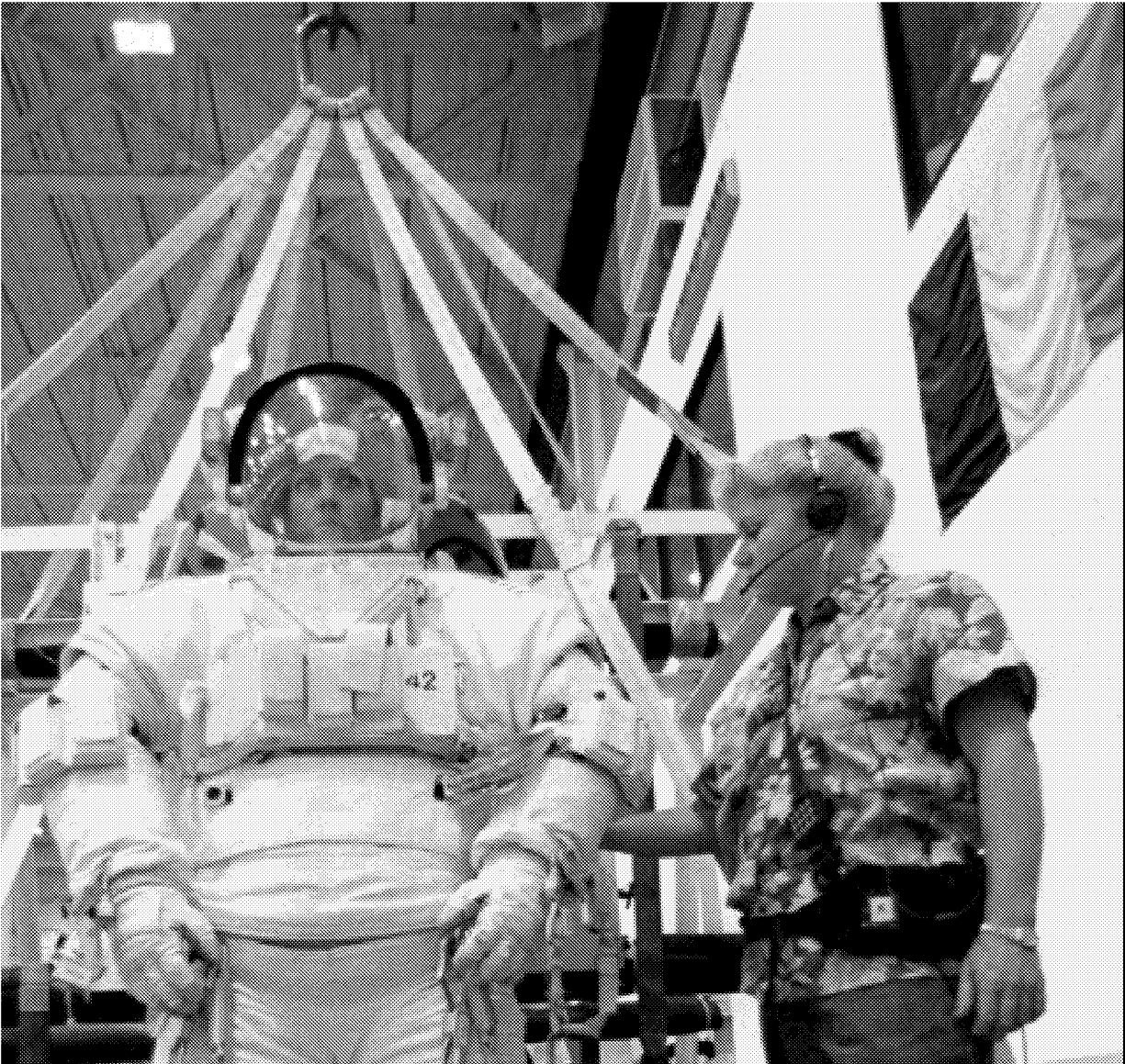
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# introduction



# Introduction

This annual report is based on the activities of the Aerospace Safety Advisory Panel in calendar year 2000. During this year, the construction of the International Space Station (ISS) moved into high gear. The launch of the Russian Service Module was followed by three Space Shuttle construction and logistics flights and the deployment of the Expedition One crew. Continuous habitation of the ISS has begun. To date, both the ISS and Space Shuttle programs have met or exceeded most of their flight objectives. In spite of the intensity of these efforts, it is clear that safety was always placed ahead of cost and schedule. This safety consciousness permitted the Panel to devote more of its efforts to examining the long-term picture.

With ISS construction accelerating, demands on the Space Shuttle will increase. While Russian Soyuz and Progress spacecraft will make some flights, the Space Shuttle remains the primary vehicle to sustain the ISS and all other U.S. activities that require humans in space. Development of a next generation, human-rated vehicle has slowed due to a variety of technological problems and the absence of an approach that can accomplish the task significantly better than the Space Shuttle. Moreover, even if a viable design were currently available, the realities of funding and development cycles suggest that it would take many years to bring it to fruition. Thus, it is inescapable that for the foreseeable future the Space Shuttle will be the only human-rated vehicle available to the U.S. space program for support of the ISS and other missions requiring humans. Use of the Space Shuttle will extend well beyond current planning, and is likely to continue for the life of the ISS.

The Panel is not concerned about the ability of the Space Shuttle to safely support immediate flight needs. Both NASA and its contractors have repeatedly demonstrated their commitment to safety and their willingness to delay launching until risks are fully understood and managed. Concern arises, however, for the longer term because the planning horizon for the Space Shuttle is too short. This has forced some improvements to be deferred until a decision is made on the Space Shuttle's successor. A shorter than realistic planned life for the Space Shuttle also has the potential to stifle those safety improvements with longer development times. Simply, these improvements will not appear to be cost effective unless a realistic service life is used in any benefit analysis.

Given the likely lead times associated with the definition, funding, and development of a new human-rated space vehicle, the Space Shuttle should be acknowledged as the primary method for humans to reach the ISS throughout the Station's life. The Panel firmly believes that a timely commitment to Space Shuttle operations for the life of the ISS from NASA, the Administration, and the Congress is essential to the long-term safety and viability of the Space Shuttle and ISS programs. This need for a timely and emphatic commitment is the overarching theme of this report.

The importance of adopting a realistic planning horizon goes beyond the obvious issues of countering obsolescence, providing adequate logistics,

and maximizing the availability of the Space Shuttles to meet mission objectives. A firm, national commitment to the use of the Space Shuttle for at least the life of the ISS provides assurance to the existing workforce that they have a viable career path. This morale booster also will help assure the availability of critical skills.

The Space Shuttle has proved to be robust and capable. Various upgrade efforts such as the Block II main engines, improvements to the solid rocket booster, and additional shielding of the heat exchanger have made significant reductions in operating risk. There are, however, other product improvement efforts that can further enhance the safety and operability of the Space Shuttle, particularly if it is to fly for an additional 20 years or more. The failure to adopt as many of these as possible in a timely manner would be ill advised. Delaying the implementation of some of the identified improvements while awaiting a decision on the service life of the Space Shuttle exposes flight crews to higher levels of risk for longer than necessary.

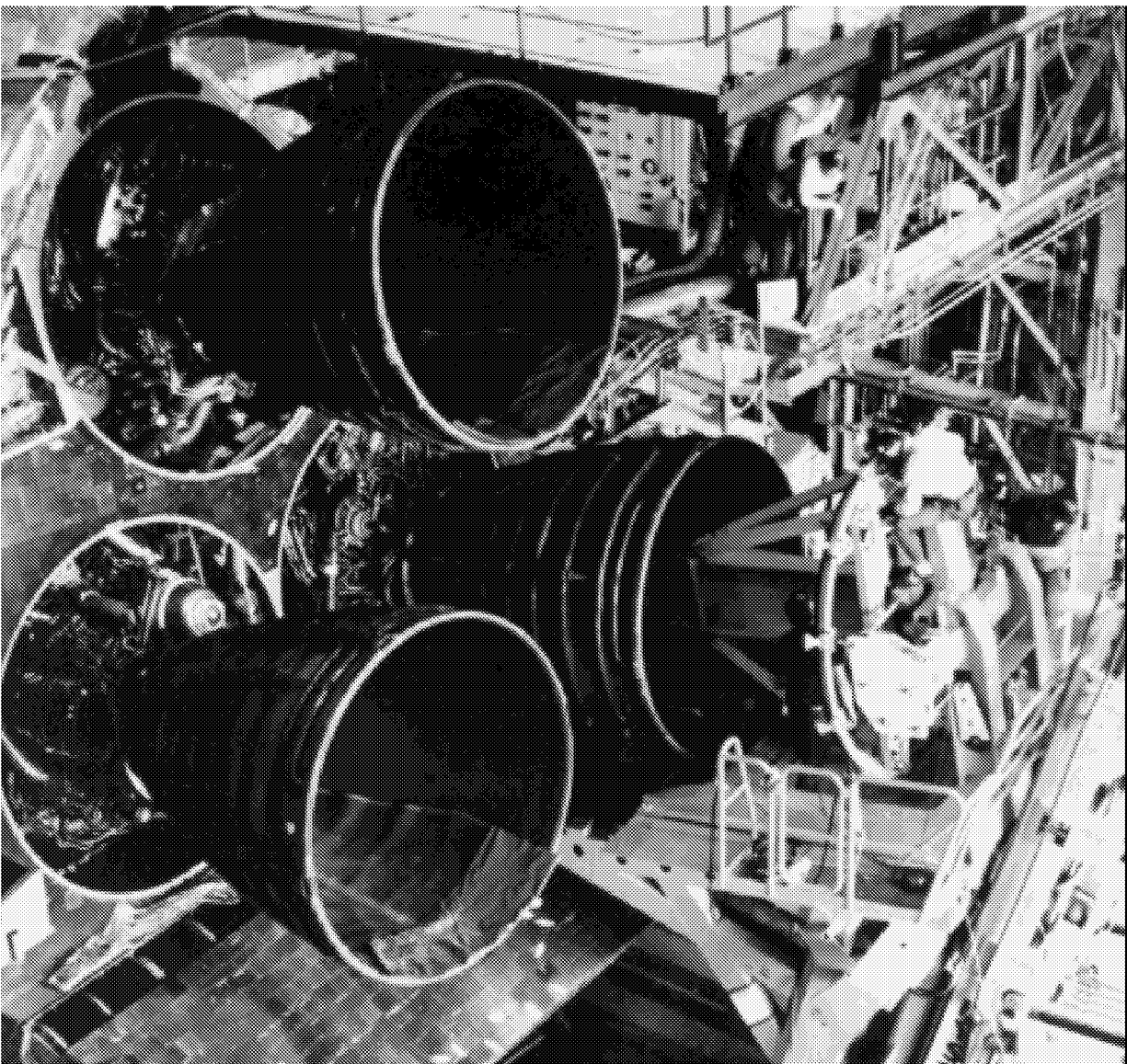
A robust, realistic, full life-cycle Space Shuttle improvement program should focus on ground as well as flight elements and consider phasing in safety improvements that will last for the entire expected life of the Space Shuttle as soon as possible.

It also is worth noting the striking parallels between NASA's workforce and its aging facilities, ground support equipment, and test and checkout gear ("infrastructure"). Both workforce and infrastructure are "invisible" issues that rarely rate front-page attention. There is a comparable tendency to "make do" with job losses and infrastructure deficiencies, relying instead on short-run fixes. In most cases these fixes are sufficient in the short-run, even as the foundation upon which NASA's space and aeronautics programs ultimately rests continues to erode. The investments needed to address these problems must always compete with what appear to be more urgent or glamorous tasks. Yet, with infrastructure, as with workforce, sustained shortfalls in these resources will eventually compromise NASA's ability to carry out its challenging mission. For this reason, the Panel believes it is important to give priority attention to infrastructure concerns in much the same way as it directed the spotlight on workforce during the past several years.

The findings and recommendations in Section II of this report and the information in support of those findings and recommendations (Section III) provide suggestions for management and planning activities as well as specific actions that the Panel believes would enhance short- and long-term safety. Appendix A contains a current roster of Panel members, consultants, and staff. NASA's response to the findings and recommendations from the *1999 Aerospace Safety Advisory Panel Annual Report* is included as Appendix B. Also in Appendix B is the Panel's assessment of the extent to which NASA's response addressed each of the issues raised. Appendix C lists the activities of the Panel in 2000.

During the year, Captain Robert L. ("Hoot") Gibson (USN, Ret.) left as a consultant to the Panel. Colonel Sidney M. Gutierrez (USAF, Ret.), a retired Space Shuttle commander, and the Honorable Robert T. Francis II, formerly vice chairman of the National Transportation Safety Board, joined the Panel as consultants.

## findings and recommendations



space shuttle program



# Space Shuttle Program

## Space Shuttle

The Space Shuttle Program (SSP) has responded well to the challenges of an increased flight rate and the need to recover from what proved to be over-ambitious workforce downsizing. While there are lingering valid concerns with regard to aging equipment and infrastructure; the quality of work paper; a changing workforce; and the need to keep pace with the launch demands of the International Space Station (ISS), the Panel is convinced that the principle, "Safety first, schedule second," is alive and well. This was amply demonstrated by the decisions to delay launches while potential safety problems were resolved. The willingness of workers to call a "time out" when they were unsure about assembly and processing tasks illustrates a commendable safety commitment.

Examples of positive achievements by the SSP include:

- Successful checkout and pre-launch activities were carried out at one-month intervals subsequent to launch of the Russian Service Module.
- A Process Control Focus Group was established and is off to a good start.
- The Block IIA Space Shuttle Main Engines have performed well in flights this year.
- The High Pressure Fuel Turbopump/Alternate has completed its two-unit certification test program. In addition, the High Pressure Oxygen Turbopump/Alternate has demonstrated a ten flight interval between rebuilds.
- Both the Reusable Solid Rocket Motor and External Tank production and delivery plans provide positive margins for planned Kennedy Space Center (KSC) operations.
- Answers to important questions about tank slosh modes during abort are now being developed.
- Simulator studies of contingency aborts to East Coast landing sites are underway.

The Panel looks forward to the successful completion of these and related efforts.

The sustained safety awareness of the SSP is reflected in a decrease in specific findings and recommendations listed below. This should not be interpreted as a lack of issues pertinent to the SSP, however. To the contrary, there are a number of Panel concerns beyond those in the findings and recommendations that will be looked into by the Panel in the coming year. Among these are the following:

- Crew escape. The Panel recommends, below, that the absence of an expanded crew escape capability be addressed as a significant safety upgrade. Crew escape will be an item of special interest for the Panel in 2001.
- Logistics. The ability of the existing logistics management structure and resources to support the Space Shuttle for its life is questionable. The Panel will be examining long-term logistics issues during 2001.

## Finding #1

The current planning horizon for the Space Shuttle does not afford opportunity for safety improvements that will be needed in the years beyond that horizon.

## Recommendation #1

Extend the planning horizon to cover a Space Shuttle life that matches a realistic design, development, and flight qualification schedule for an alternative human-rated launch vehicle.



## Finding #2

There is no in-flight crew escape system for the Orbiter other than for abort below 20,000 feet during a controlled glide.

## Recommendation #2

Complete the ongoing studies of crew escape design options and implement an improved system as soon as possible.

### Finding #3

Redundant hydraulic lines for the three orbiter hydraulic systems are not adequately separated to preclude loss of all hydraulic power in the event of a single catastrophic failure of adjacent hardware.

### Recommendation #3

Provide the same degree of separation of redundant critical hydraulic lines as is given to redundant critical electrical wiring.

## Launch and Landing

The processing of the Space Shuttle preparatory to flight at KSC is a complex, labor-intensive, mission- and safety-critical activity. The processing is controlled by requirements that flow down to the work floor in the form of work instructions or “work paper.” Ground processing at KSC also involves numerous hazardous operations.

Because of the importance of KSC ground processing to overall Space Shuttle safety, the Panel maintains a standing team devoted to fact-finding at the center. A special task group has also been formed to address the ongoing initiative to improve work paper to support KSC ground processing.

In addition to the quality of the work instructions, the KSC team focused during the year on other factors related to ground processing that have the potential to impact Space Shuttle and KSC worker safety. Among these are workforce composition and critical skills, morale, the extent and condition of ground support equipment and fixed infrastructure, and center policies and organization. The KSC team assesses these factors through regular visits that includes onsite examinations and both scheduled and impromptu conversations with the workforce. This provides continuity to the team’s evaluation to help see beyond the short-term impact of highly publicized events, such as the hiring of new personnel and incidents during processing and launch attempts.

Two specific findings and three recommendations dealing directly with launch processing at KSC follow.

#### Finding #4

The ongoing effort to improve the work paper used at KSC by incorporating outstanding deviations and clarifying and simplifying the work instructions is proceeding well. Some lesser effort has been focused on improving the vehicle engineering drawings and reducing the engineering orders (EOs) they contain.

#### Recommendation #4a

Continue vigorous efforts to upgrade the work paper, even as the flight rate increases, in order to maintain the positive momentum that this worthwhile initiative has generated.

#### Recommendation #4b

Focus additional effort on updating vehicle engineering drawings with the objectives of incorporating as many EOs as possible and assuring the clarity of all information.

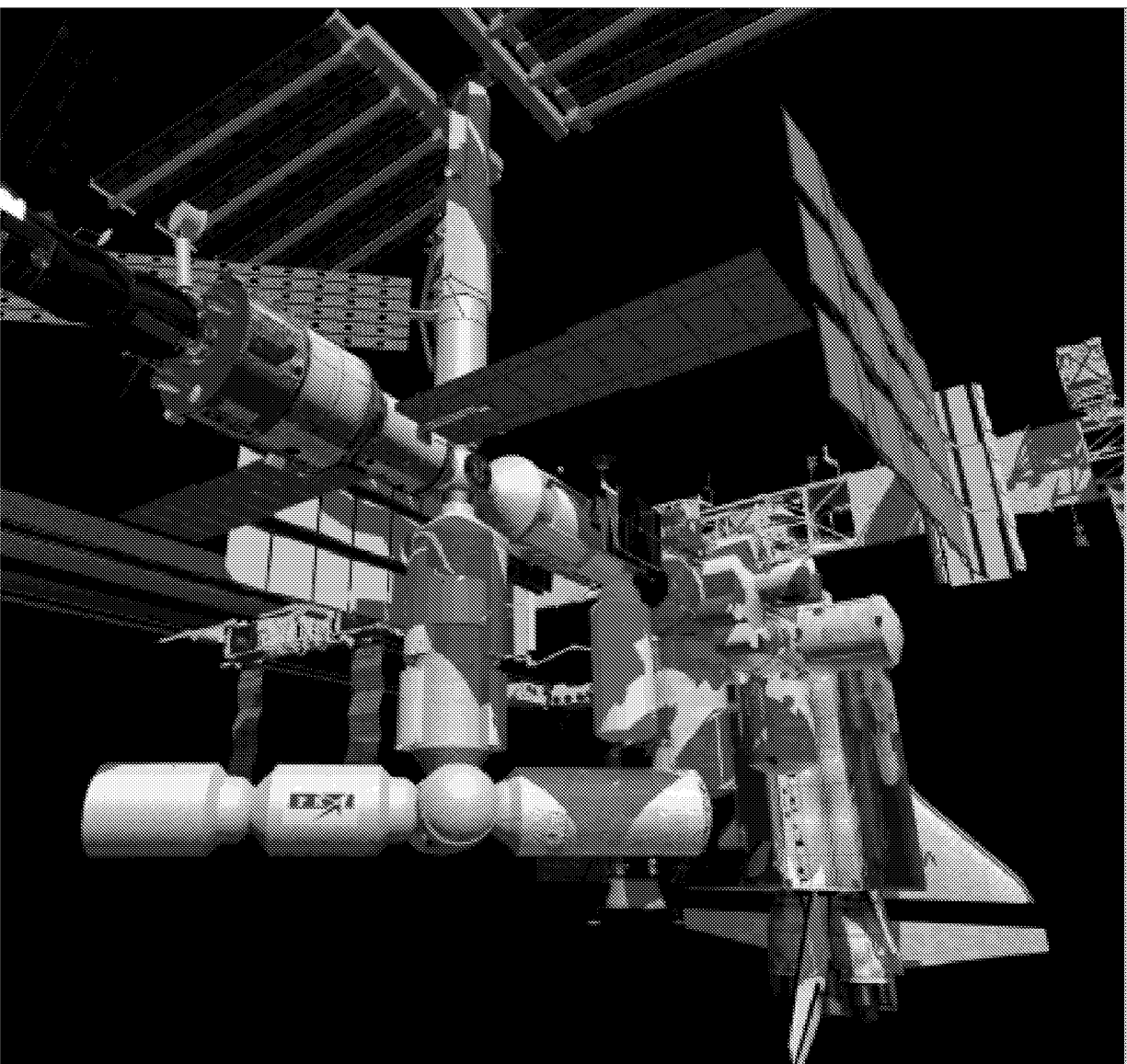
## Finding #5

The KSC facilities, ground support equipment, and test and checkout gear to support Space Shuttle processing and launch operations continue to age. The status of the potential readiness of these essential assets has been projected, but there is no detailed, funded plan to ensure that this aging infrastructure can safely support the Space Shuttle for its likely operational life.

## Recommendation #5

Develop a detailed plan and budget to maintain and upgrade the KSC assets that are essential to the safe operation of the Space Shuttle for its reasonably expected flight life so that an appropriate infrastructure life extension program can be implemented.

international space station  
and crew return vehicle



# International Space Station and Crew Return Vehicle

## International Space Station (ISS)

With the launch of the Service Module, the ISS has begun the long-planned program to finish assembly on orbit. The first three-person crew arrived on board in October, and the Space Shuttle launch rate has increased. Over the next few years seven to eight Space Shuttle launches per year plus Russian launches for resupply will be carried out. This higher launch rate raises several issues of logistics, training, and operations, some of which are reflected in findings and recommendations in other sections of this report.

The danger to the ISS of impact from micrometeoroids and orbital debris (MM/OD) has been reported over the last several years in the Panel's reports. The ISS still remains more vulnerable than it is expected to be in its final configuration because shielding for the Service Module is not scheduled to be available for assembly for three years. The ISS Program is keenly aware of this issue and continues to seek a way to accelerate manufacture and assembly. The Panel will continue to monitor this and other MM/OD issues.

Over several years, the Panel also has addressed issues associated with damage detection, assessment, control, and repair. Several years ago the ISS Program created an Integrated Task Team to deal with these issues and good progress has been made. The Panel intends to thoroughly review this area during the upcoming year.

There is a single finding with respect to the ISS.

## Finding #6

Due to the rapid pace of ISS assembly launches and the many and varied resulting configurations, Multi-Element Integration Testing (MEIT) with operational loads of Portable Computer System (PCS) software is limited and, in some cases, may only be accomplished in the brief time allocated for regression testing.

## Recommendation #6

Strive to accelerate scheduled releases for PCS software. Be prepared to delay schedules, if necessary, to assure that MEIT testing and astronaut training with the flight loads of PCS software are thorough and complete.



## Crew Return Vehicle (CRV)

A CRV team within the Panel was established early in the year to focus on the safety aspects of the NASA effort to develop a suitable “lifeboat” for the ISS. It appears that good progress is being made in validating the parafoil deployment system and in meeting the requirements of the newly-developed NASA Human Rating Standard. The X-38 (V201) Space Flight Test Plan for the final validation flight from the Space Shuttle on orbit scheduled for early 2002 also is progressing.

As discussed in last year’s report, the ISS Program has decided to use one seven-person U.S.CRV and one three-person Russian Soyuz CRV as the configuration at assembly complete. The Panel is concerned about the possible unavailability of the Russian-built Soyuz and the subsequent impact on full-crew operation over the life of the ISS. However, the Panel has received assurances from NASA management that Soyuz availability is being monitored closely by NASA teams within Russia, and that in any event no deviations from the current safety rules will be permitted.

During a drop test of the X-38 at the Dryden Flight Research Center (DFRC), the test vehicle exhibited severe pitch and roll oscillations as part of repositioning during the drogue chute deployment prior to the main parafoil deployment. While within requirements, these oscillations were certainly undesirable. The CRV project has already taken steps to dampen these repositioning dynamics, and the subsequent X-38 Phase 3 Drop 6 test exhibited much more benign repositioning behavior.

Specific findings and recommendations follow.

### Finding #7

The specific definition of many of the tests identified in the draft X-38 (V201) Space Flight Test Plan appears to be lagging. The return from orbit test specified by this plan is the final planned validation of the X-38 vehicle and derived CRV.

### Recommendation #7

Establish a timetable for the early completion of the detailed X-38 (V201) Space Flight Test Plan. Sufficient time must be made available for a thorough review process and for possible changes in the plan resulting from the review.

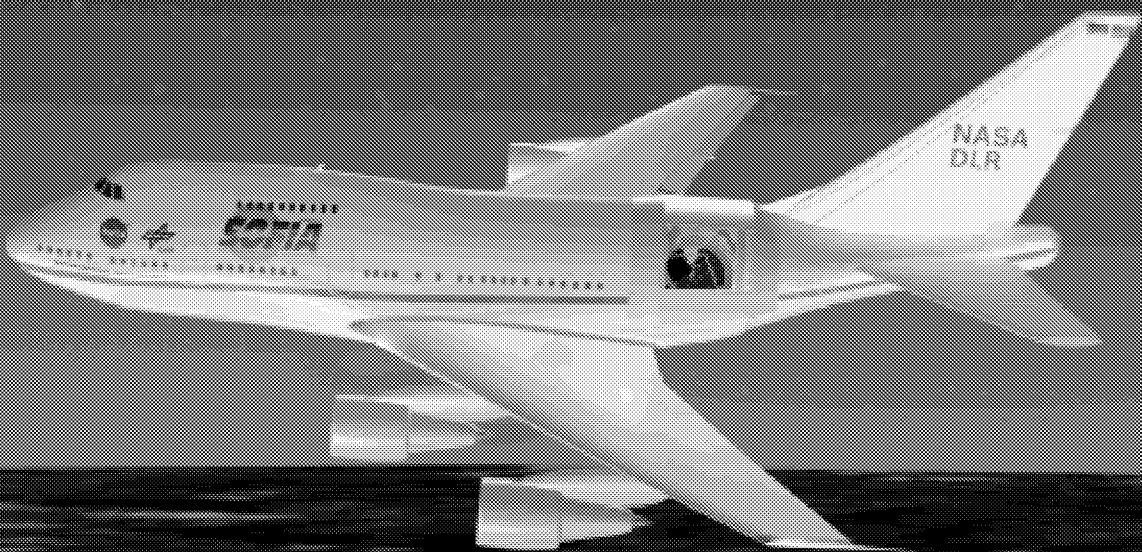
## Finding #8

Because of the innovative processes used, there is some possibility that all of the design knowledge related to safety issues that has been acquired by the NASA X-38 team may not be transferred to the contractor selected to build the operational CRV.

## Recommendation #8

Develop a plan to ensure that all of the design experience gained by NASA in the X-38 technology validation effort is transferred to the contractor selected to produce the operational CRV.

aerospace technology



# Aerospace Technology

The Aerospace Technology Enterprise accelerated the shift from predominantly near-term aeronautical technologies to projects that relate to the needs of future space transportation systems. The largest impact of this shift was noted at the Langley Research Center (LaRC) where the skills of the staff working on the cancelled High Speed Transport (HST) and Advanced Subsonic Research (ASR) programs were not a good match for new Intelligent Synthesis Environment (ISE) and Space Transportation activities. Although it is disturbing that the Enterprise has significantly reduced resources for the aviation sector, it is encouraging to note that the Aviation Safety Program has been maintained and has taken up some of the safety projects that were formerly in the cancelled aeronautics programs. On the other hand, the Panel is concerned that the wind tunnel activity sponsored by government and industry at both LaRC and the Ames Research Center (ARC) appears to be declining.

In the general aviation area, the Small Aircraft Transportation System (SATS) Program is a natural follow-on to the Advanced General Aviation Transport Experiments (AGATE) Program. SATS is aimed directly at lowering cost and increasing safety at the lower end of the general aviation spectrum where the accident rate is the highest. Clearly, this is a large challenge. However, the program fully recognizes this and has a strong emphasis on flight training, crashworthiness, and the demonstration of high reliability of inexpensive flight components.

There has been an increase in emphasis on the technologies associated with unoccupied vehicles and the use of them for testing advanced concepts. The various Unoccupied Air Vehicles (UAV), such as Perseus and X-34, form a comprehensive set of technology expansion efforts in the high altitude/long duration flight region and contribute to the ability to provide earth science information and subscale models for proof-of-concept flight demonstrations.

The NASA/FAA cooperative effort to improve safety in the civil aviation area is excellent. The "Future Flight Central," a full simulation of a large city control tower housed at ARC, will improve existing and future control tower safety. The Advanced Air Transportation Technologies Project is making good progress towards improving the efficiency and safety of the Air Traffic Control system.

The Panel has also noted that some Aerospace Technology programs are considering replacing the use of traditional factors of safety with Probabilistic Risk Assessments (PRAs). The Panel has long supported PRA as a design tool to assess trade-offs; however, there is concern with using PRA as the primary means of assuring adequate design margins. The Panel plans to examine this issue in more detail.

The "Design for Safety" concept centered at ARC has admirable goals but seems to focus on the premise that model-based digital prototyping can replace the individual expertise currently needed for the design process.

To do this successfully, a high degree of validated expert knowledge and probabilistic data must be employed in the system modeling and programmed reasoning. The panel will review the progress on this effort during 2001.

An ongoing research program at the Dryden Flight Research Center (DFRC) is examining an Advanced Aeroelastic Wing (AAW) on an F/A-18 aircraft. The flutter limits of the F/A-18 AAW configuration were judged to be satisfactory by comparison to the original F/A-18 wing. Detailed flutter analyses were performed or are planned based on the differences between the original and test wings. Since there can potentially be other significant variation in the two wings, there may be differences in the flutter boundaries that may not be obvious. The Panel will continue to follow the efforts of this project.

Specific findings and recommendations follow.

## Finding #9

The overall ARC flight operations, including the Stratospheric Observatory for Infrared Astronomy (SOFIA) science program management communication and coordination, have improved significantly but still merit close management oversight with specific attention to early and continuous integration of flight operations personnel into the project.

## Recommendation #9

ARC flight operations personnel should continue to increase their cognizance of the aircraft modification activities to insure timely coordination and implementation of flight operations requirements.

### Finding #10

Not all Aviation Safety Officers (ASOs) report directly to their Center Directors.

### Recommendation #10

ASOs should report directly to their Center Directors.



cross program areas



# Cross Program Areas

## Workforce

This past year NASA declared downsizing and hiring freezes at an end and initiated a modest expansion of the workforce, abandoning the personnel targets that were initially established by the Zero Base Review (ZBR) in the mid-1990s. The Panel applauds this change and believes it will, over time, lead to a workforce better able to carry out NASA's mission more safely.

This shift in direction provided badly needed relief, in particular, to the Office of Space Flight centers—KSC, Johnson Space Center (JSC), and Marshall Space Flight Center (MSFC). These centers were experiencing growing shortages in critical skills and a general lack of human resources needed to sustain the increasing flight rate of the Space Shuttle and ISS assembly. NASA contractors were facing comparable shortfalls in personnel after several years of downsizing. Recruitment of NASA's next generation of leaders had also ground to a halt.

All at once, however, the centers and contractors found themselves facing the new challenge of carrying out this change in workforce direction. Recruitment and training of "fresh outs," a task that had been all but abandoned, suddenly assumed high priority along with locating experienced persons to fill critical skills shortages. In addition, a number of senior employees have continued to retire and some leave NASA for other employers. Stress levels among some employees still are a matter of concern. In other words, workforce issues continue to merit the Panel's attention.

Three findings and seven recommendations on workforce are presented below.

### Finding #11

The critical skills challenge faced by NASA and its contractors in the Space Shuttle and ISS programs continues despite resumption of active recruiting of experienced and new employees.

### Recommendation #11

Provide more effective incentives to retain employees with critical skills in such areas as Information Technology and Electrical/Electronic Engineering. Continue active recruiting of experienced and “fresh-out” employees, using appropriate incentives when necessary.

## Finding #12

NASA's recent hiring of inexperienced personnel, along with continuing shortages of experienced, highly-skilled workers, has produced the challenge of training and integrating employees into organizations that are highly pressured by the expanded Space Shuttle flight rates associated with the ISS. There is no systematic effort to capture the knowledge of experienced personnel before they leave. Stress levels within the workforce are a continuing concern.

### Recommendation #12a

Provide active mentoring and other career development incentives to bring new employees to full productivity as rapidly as can be accomplished with safety remaining paramount. Expand resources and delivery methods available to Agency level training programs to enable greater participation at Center and program levels.

### Recommendation #12b

Continue efforts, in partnership with NASA contractors, where appropriate, to provide hands-on experience.

### Recommendation #12c

Establish processes that capture the knowledge of experienced personnel before they leave or retire.

### Recommendation #12d

Help employees deal positively with work-related stress.

### Recommendation #12e

Implement an evaluation of the processes used to develop new hires into productive members of the workforce.

### Finding #13

Recent downsizing and limitations on hiring have produced a workforce with aberrations in normal career development patterns and a potential future shortage of experienced leadership.

### Recommendation #13

Develop and implement a long-term workforce plan, focused on retention, recruitment, training, succession, and career development needs, with at least a five-year time horizon that will ensure the availability of competent and experienced leaders. Also provide a strengthened capability in organizational development.

## Computer Hardware/Software

Computer issues have continued to play an important role in NASA's activities during the past year in such areas as computer security, ISS computer systems, Space Shuttle avionics upgrades, ground support computer systems, and independent verification and validation (IV&V) activities. During 2000, the Panel continued its attention to issues raised in its 1999 report, in particular computer security and Space Shuttle avionics upgrades, that remain of concern this year. Rather than introduce new, similar, items in this year's report, the Panel has classified some of the items from last year as continuing. The Panel is satisfied with the initial directions NASA is taking, but realizes that it will take some time for the tasks to be completed. The Panel will continue to monitor progress on these items. It also has investigated a number of new issues, such as changes in the IV&V Facility organization, ISS computer systems, and additional aspects of computer security.

The Checkout and Launch Control System (CLCS) is one of the areas the Panel has been following for several years. In the middle of this year, NASA made a major change in the organization of this project, bringing in a new program manager, transferring significant tasks to contractors, extending the completion date, and providing additional funding. The Panel will continue to follow these changes in the next year.

This year has seen major accomplishments in ISS computer systems. The software for the initial ISS stages was completed on time, successfully launched, and is operating on the ISS computer systems. NASA also has successfully agreed with the International Partners for sustaining engineering activities in support of the ISS computer systems. These are important steps forward. Nevertheless, the Panel encourages NASA to continue its efforts to obtain the source code for all software used on the ISS. Also, NASA is having a difficult time keeping the utilization of the ISS computer systems at the level specified in the requirements. An upgrade to the ISS Multiplexer/Demultiplexer (MDM) would help substantially.

Questions about the development of the PCS arose during the year. The Panel's investigation did not reveal any safety compromises. There are, however, concerns about the design of the PCS user interface. Now that the ISS is permanently inhabited, experience is being gained with the PCS, and it will be possible to see how well it functions. The Panel will continue to study this during the coming year.

In 2000, NASA began its computer security program in earnest. It completed most of its first round of security training, conducted initial security evaluations, and had an external contractor conduct penetration studies of systems at three NASA centers. Further, NASA withstood several hostile attacks during the year without major consequences. Nevertheless, the Panel has some concerns that are discussed below.

NASA made a major change in the organization of its agency-level software assurance and IV&V activities. The responsibility for operation of

the IV&V Facility in Fairmont, West Virginia, was transferred from ARC to the Goddard Space Flight Center (GSFC). This change is reasonable because of the geographical proximity of the Facility to GSFC and the operational nature of the Facility's work. Efforts to strengthen the utilization of IV&V throughout NASA were included in the change. It is too early to assess the impact of this change. However, the Panel has two concerns that are also addressed later in this report.

In summary, NASA has made a number of important strides forward in its computer activities, but areas of concern to the Panel remain.

## Finding #14

While NASA has made major changes to emphasize the need to utilize IV&V on safety critical projects, the technology is not well understood by program managers and other relevant NASA personnel.

## Recommendation #14

Develop an appropriate user-centered course and require software assurance awareness training for all levels of management to help them become more cognizant of the IV&V processes and the value IV&V brings to a final product.



### Finding #15

NASA's reorganized IV&V activities place more emphasis on enforcing requirements than on researching and developing methods to perform IV&V for such emerging technologies as neural nets and expert systems.

### Recommendation #15

Ensure the continuation of a strong, focused software assurance and peer reviewed IV&V research program.

## Finding #16

NASA has initiated a well-founded, broadly encompassing computer security program to ensure that its computer systems are protected from hostile attacks, but development of security plans for all systems is lagging. Also, the function of Computer Security Officer has typically been added to the responsibilities of systems administrators.

### Recommendation #16a

Complete and maintain security plans for all appropriate computer systems and ensure that the computer security program is sustaining.

### Recommendation #16b

Ensure that computer systems administrators are properly trained in computer security.

### Finding #17

NASA has initiated plans to have its critical systems processes evaluated according to the Capability Maturity Model (CMM) of the Software Engineering Institute and to work toward increasing the CMM level of its critical systems processes.

### Recommendation #17

Implement the plan and ensure that all critical systems development programs comply.

## Finding #18

The MDMs on the ISS are already at the 65 percent utilization design limit of their central processor unit (CPU) with four major software releases still to come. There is no identified method for accommodating the inevitable increasing demands on the CPU.

## Recommendation #18

Proceed expeditiously to upgrade the MDM computer system.

## Extravehicular Activity (EVA) and Radiation Protection

Following a prolonged period of minimum activity resulting from delays in the assembly of the ISS, EVA rolled into high gear in 2000. The trouble-free execution of these operations reconfirmed the value of detailed planning by the EVA Project Office and intensive, realistic pre-mission training.

The current ISS assembly schedule, which requires a significant ramp-up of EVA, raises concerns regarding the ability to sustain those operations with the current inventory of Extravehicular Mobility Units (EMUs). A dropped and damaged EMU caused a perturbation in the EMU logistics chain, highlighting the precarious state of that system. The Panel believes it is time to invest in the development of a next generation space suit to replace the 20 year-old technology EMU and Portable Life Support System (PLSS).

There will be future missions into environments that are too hostile for safe human EVA. It is therefore essential to exploit the rapidly evolving field of robotics to provide alternatives to EVA as humans venture into deep space.

During 2000, the National Research Council, Space Sciences Board on Atmospheric Sciences and Climate, in response to a request by NASA, published a report, "Radiation and the International Space Station: Recommendations to Reduce Risk." The report makes six recommendations that span mission operations, intra-agency and inter-agency radiation research coordination, and space weather. The Panel has reviewed NASA's intended responses to that report and finds them well founded.

NASA has, within the recent past, established a very credible research program to determine the biological effects of radiation in space and to develop effective countermeasures. Despite experience gained in nuclear weapons programs and in the military and civilian nuclear power programs, the long-term effects of exposure to ionizing radiation are not fully understood. A realignment of priorities may be appropriate with emphasis on the development of more effective dosimetry, not only for near-term requirements, but also for future exploration of space.

Specific findings and recommendations on EVA and radiation protection follow.

## Finding #19

Even though the most significant unknown in crew composite radiation exposure may be the contribution of neutrons, the Evolutionary Plan for the Crew Health Care System (CHeCS) only lists a neutron monitor as a “Future Medical Requirement,” and a project to fly a neutron detector is not planned until Increment 2.

## Recommendation #19

Accelerate the development of effective and reliable personal and area neutron dosimeters.

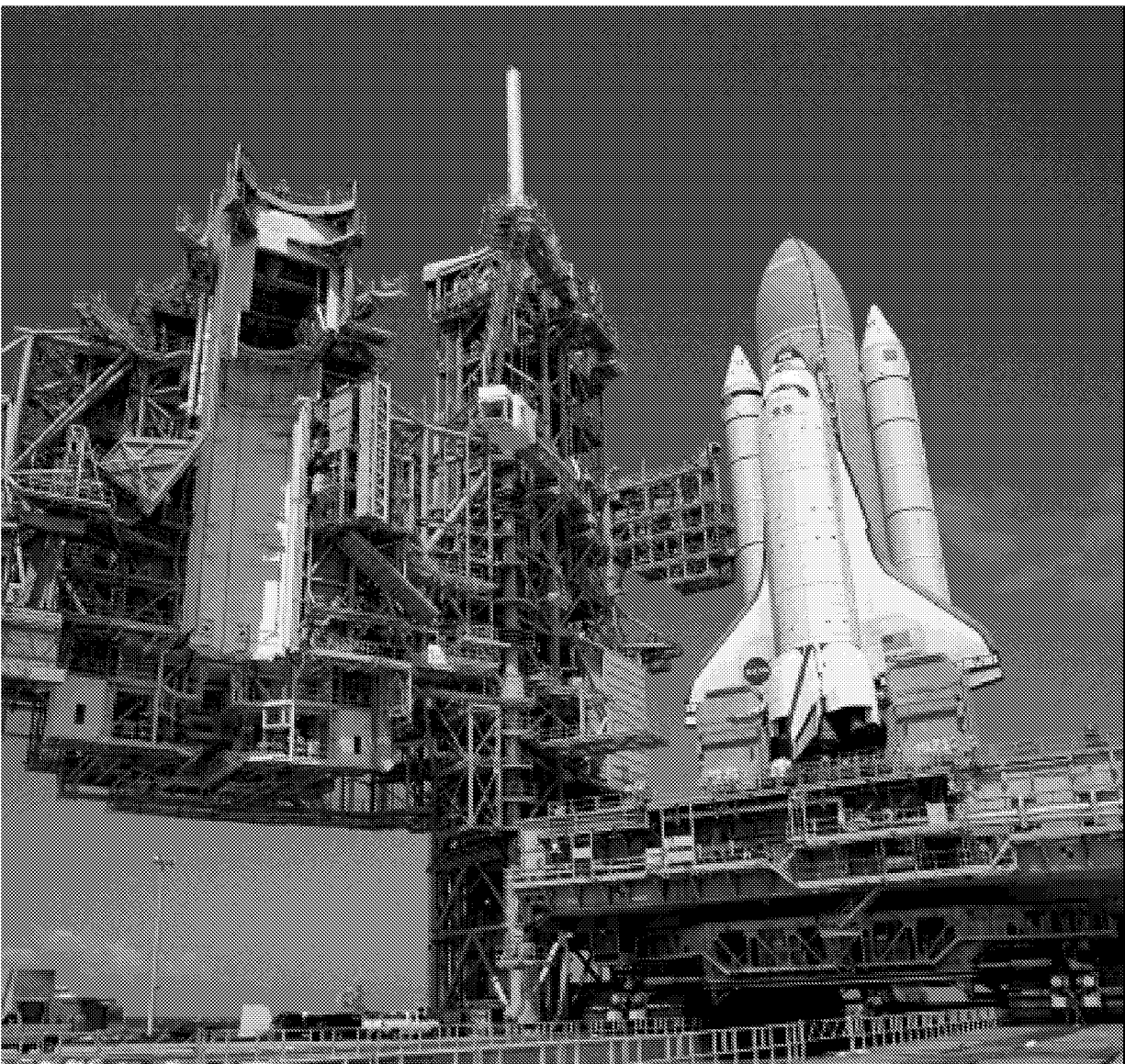
### Finding #20

The current EMU is adequate for the near-term needs of the ISS and the Space Shuttle, but its obsolescent technology, high cost, and other limitations make it unsuitable for future exploration and development of deep space.

### Recommendation #20

Initiate a high priority program to design and develop a next generation space suit.

information in support of  
findings and recommendations





# Space Shuttle Program

## Space Shuttle

### Ref: Finding #1

There will likely be no human-rated replacement for the Space Shuttle for many years. Nevertheless, the planning horizon for Space Shuttle safety and reliability upgrades and for logistics spares is presently set at five years. This shorter than realistic expected life for the Space Shuttle has the potential to stifle those safety improvements which require longer development times. NASA should reassess its Space Shuttle planning horizon.

## Ref: Finding #2

The Presidential Commission on the Shuttle Challenger Accident addressed crew escape in their report and recommended that NASA, "Make all efforts to provide a crew escape system...." NASA responded by initiating crew escape studies. Phase I was intended to provide a minimum system prior to return to flight. Phase II was not tied to the return to flight schedule and was intended to provide an automated escape system at a later date uncompromised by the tight return to flight schedule. The Phase II study concluded that an automated escape system was feasible for certain flight regimes and recommended further trade and design studies and a focused development program.

Over the lifetime of the Space Shuttle, a reliable post-launch crew escape system will provide the largest potential improvement in crew safety. NASA has completed or has underway a number of studies that also suggest such a system is feasible. The time is past due for the implementation of a more capable crew escape system.

### Ref: Finding #3

The routing of supposedly redundant hydraulic systems in close proximity, one to another, inside the Orbiter is not good engineering practice and could contribute to a vehicle-threatening situation; one event could simultaneously compromise all three systems. A redesign to avoid hydraulic systems in close proximity should be started now.

## Launch and Landing

### Ref: Finding #4

Considerable effort has been applied to improving the Space Shuttle processing work documentation at the Kennedy Space Center (KSC). The United Space Alliance (USA) has formed a team of experienced engineers and technicians and tasked it with updating the quality and accuracy of the paperwork. The team has developed a revised format for the books of work instructions that makes extensive use of graphics and follows the prevailing state-of-the-art in typography and layout. This application of additional management emphasis and resources has led to a reduction in the backlog of unincorporated changes and the production of new procedure specifications in a more user friendly format.

The goals set by USA for 2000 have essentially been met. For the unincorporated changes (deviations or "devs"), the backlog has been reduced over 20 percent. As of this writing in late November, there were 4,185 devs open as compared with a goal of 3,969 for December 31, 2000. This 20 percent reduction was accomplished even though approximately 400 deviations per month are still being initiated to the work documents currently in use. Nevertheless, the absolute number of outstanding devs is still too high, and continuing efforts are needed to reduce the count further.

To date, over 600 of the vehicle and support equipment assembly, test, and checkout procedures ("books") have been reviewed for new format conversion. This surpassed the goal of 528 targeted for December 31, 2000. Of the 600 books reviewed, approximately 10 percent have been published and received approval for use. Results have been excellent, with essentially no changes required during execution of the procedures. The ground systems facilities document conversion (to MAXIMO software) is expected to achieve 85 percent of this year's goal.

Less effort has been focused on the improvement of engineering drawings than on upgrading the books of work instructions. As a result, there are still too many unincorporated engineering orders (EOs) on the work drawings. There was at least one processing problem during the year (the loss of an elevon tile) the root cause of which was traced to confusing drawings. It has been reported that some drawings have been updated so many times that they are virtually illegible. NASA and its contractors did focus some effort on improving engineering drawings, but more work is needed. A concerted, continuing effort by the vehicle systems design organizations, such as the one focused on work instructions at KSC, is clearly warranted and should be started as soon as possible.

The time required and resource expenditures to complete these activities will be considerable. Additionally, the production of new work documentation and drawings and the transition to their use must occur

during ongoing Space Shuttle operations. Handling both an increased launch rate and a continued, intensive effort to upgrade paperwork and drawings will require dedication and careful management. Even with the increased workload generated by more frequent launches, however, these improvement efforts should continue to receive high priority so the benefits can be realized as soon as possible and potential future problems can be avoided.

## Ref: Finding #5

The Space Shuttle is destined to be NASA's human-rated launch vehicle for the foreseeable future. Like many contemporary aircraft, the Space Shuttle can have its life extended almost indefinitely through an appropriate product improvement program. Issues such as parts obsolescence in the flight elements and their safety improvement are being addressed through the ongoing Space Shuttle upgrades activities. This effort will make the vehicle itself safer and easier to maintain. There are, however, in addition to the flight elements, numerous support elements on the ground that are necessary for the safe preparation, test, checkout, and launching of the Space Shuttle.

Many of the safety critical ground assets for the Space Shuttle are at KSC. Most of these assets are 20 or more years old, and many are legacies from Apollo or earlier programs. Included are test equipment and facilities; unique ground equipment such as the crawler transporters; ground support equipment; launch facilities; and the traditional "infrastructure" items such as buildings, cableways, and piping. For some time, the maintenance of these assets has focused primarily on assuring their immediate availability for the next launch. Much long-term maintenance and most upgrades have been deferred or never planned due to a lack of resources. As a result, the ability of these key assets to support the Space Shuttle for its expected flight life has become questionable.

Both NASA and its contractors have devoted significant effort to ensuring that ground assets are available and safe for each launch. There is a firm commitment to call a "time out" from launch activities if there is a question about the health of any of the ground systems. Assessments also have been made of the extent to which maintenance, refurbishment, and replacement have fallen behind the aging of the various systems. There is not, however, a coordinated and funded plan to deal with this issue for the foreseeable service life of the Space Shuttle. Such a plan is needed forthwith as part of an overall effort to define the likely service life of the Space Shuttle and to plan for its continued safe, efficient, and effective operation.

# International Space Station and Crew Return Vehicle

## International Space Station (ISS)

Ref: Finding #6

The assembly sequence for the ISS requires many launches and results in a myriad of ISS configurations with associated requirements for the Portable Computer System (PCS) software. The PCS is the primary astronaut interface to the system, especially in monitoring the station and in troubleshooting in the event of anomaly or emergency. This PCS software is necessary for Multi-Element Integrated Testing (MEIT) as well as for astronaut training for each flight. Problems can result when the software used for testing or training is not the same as the final flight load. The potential problems are greater when the software's basic functionality is changed than when the updates between testing and deployment only involve improvements in the displays. Regardless of the motivation for or nature of a software upgrade, adequate testing with crew participation is necessary before it is committed to flight.

The Panel understands that MEIT testing is often paced by software delivery, especially for the PCS. To maximize the amount of testing of the basic system, work has been scheduled to proceed without the final software for the PCS. There are plans to test the final PCS load via regression testing. This is, no doubt, the most expeditious way to proceed, but it does restrict the amount of time for testing, catching errors, and, especially, for testing and training with astronaut participation. The ISS program should therefore use caution to ensure that regression testing is truly sufficient to assess the flight software and prepare the crews adequately for their mission.

## Crew Return Vehicle (CRV)

### Ref: Finding #7

Over the past several years, the Panel has followed the X-38 CRV technology validation program with particular interest to the issues related to the safety of the CRV occupants. The scheduled space flight test of the X-38 vehicle 201 from the Space Shuttle on orbit is a key element in the safety validation of the CRV. While many of the individual elements of the X-38 CRV and its systems have been individually tested or validated, this test from space is a key event in the validation program. Every effort must be made to ensure the success of this test. The completion of a detailed test plan at a very early date is essential to providing for a thorough review of the plan by all of the interested parties, including a possible independent review team.



## Ref: Finding #8

The X-38 CRV technology validation program is at a critical stage. An aerospace contractor is in the process of being selected to design and produce the operational crew return vehicles. During the technology validation phase of the program, the NASA team conducted many design studies, safety analyses, and tests on various elements and systems to be used in the operational vehicles. This process of a NASA hand-off to a contractor is innovative. As a result, there is little experience in dealing with the necessary information and technology transfer. This leads to a concern that the wealth of knowledge gained by the NASA X-38 team may not be completely transferred to the selected contractor. Although there has been involvement by the potential contractors in the NASA portion of the program, there needs to be a comprehensive plan to ensure that all of the design and safety knowledge acquired by NASA is fully utilized by the contractor. One approach might be to use NASA engineers to support the contractor's design team. Other ideas may be forthcoming. In any event, the lessons learned by NASA should not be allowed to slip away from the designers of the production vehicles.

## Ref: Finding #9

Safety-related issues associated with the Stratospheric Observatory for Infrared Astronomy (SOFIA) include the Boeing 747SP modifications for carrying the German-provided telescope and plans for acquiring FAA supplemental-type certification. This also covers significant modifications such as skin replacements. The aerodynamic and structural tests of the modification have proceeded with satisfactory analytical results and will be validated by flight tests in 2001.

A SOFIA Cockpit Working Group, composed of United Airlines (UAL), Universities Space Research Association, Raytheon, and NASA, has been established with purview over the cockpit avionics configuration, and intends to meet all regulatory requirements and conform to UAL operational guidelines. The cockpit configuration is not on the SOFIA schedule critical path, and the applicable regulations, avionics technology, and the UAL fleet configurations are all evolving. Thus, the decision on the final configurations has been delayed until required by the development schedule. As a result, the flight operations for SOFIA are planned for two phases: a flight operations test phase and a science mission phase.

## Ref: Finding #10

Experience has demonstrated that the best aviation safety performance comes when the chief executive officer of a facility personally retains the role of top safety official. This cannot be effected within NASA if the Aviation Safety Officer (ASO) is organizationally removed from the Center Director. Although each NASA center has a designated ASO, these ASOs do not all report directly to their Center Directors. While ASOs may have ready access to their Center Directors, their independence in reporting safety problems can be compromised if they are not direct reports. In order to assure the prominence of aviation safety within each of the NASA centers, all ASOs should report directly to their Center Directors.

# Cross Program Areas

## Workforce

Ref: Findings #11-13

The Panel was gratified that NASA in FY 2000 resumed a more realistic approach to meeting its workforce requirements. After several years of downsizing and hiring restrictions, NASA permitted its Field Centers to resume modest hiring of persons to fill identified gaps in critical skills and recruitment of recent graduates (“fresh outs”) to provide engineering and management leadership in the future. The United Space Alliance came to a similar conclusion in regard to its Space Shuttle processing duties at KSC and began augmenting its workforce that had been excessively cut over the prior two years.

These positive changes came after two years of intensive review of workforce and infrastructure carried out by the Core Capability Assessment (CCA). This review documented that the downsizing and Zero Base Review (ZBR) targets had especially affected the Office of Space Flight (OSF) centers. Extensive fact-finding by the Panel at KSC, JSC, and MSFC revealed that an increasing number of critical skills were either lacking or one-deep. The inability to fill these vacancies except by internal NASA transfers raised serious questions about OSF’s capability to meet the expanded Space Shuttle flight rate associated with assembly of the ISS. And, as noted previously, the near total absence of hiring of recent graduates raised the threat of leadership shortfalls as senior NASA leaders reached retirement age.

The approved hiring levels were designed to provide relief for the most urgent skill gaps, and make a credible beginning in recruitment and hiring of fresh-outs. In addition, there were clear intangible benefits to the workforce that flowed from the reality that human space flight still had a future at NASA. Improvements in employee morale were frequently cited to the Panel during its fact-finding trips. KSC was approved for approximately 160 new hires (with an immediate emphasis on safety inspectors); JSC was approved for approximately 170; and MSFC for about 215. Each center was directed to use at least 50 percent of these additions for entry-level fresh-outs. It is noteworthy that with these additions the employment levels at the OSF centers are still at least 20 percent below those that prevailed at the time of the ZBR (1994–95).

The decision to change workforce policy was reached early in calendar year 2000. Hence, there was initially real doubt among human resources (HR) staff at the centers whether hiring of fresh-outs was feasible since recruitment of the best and the brightest in the 2000 graduating class had been underway for months. But the response to NASA’s recruitment efforts was excellent, far in excess of expectations. HR officers cited instances where graduating engineers walked away from earlier offers in

order to work in the space program. It is likely that this recruiting success will continue. The large number of retirement eligibles at each OSF center ensures that vacancies will need to be filled.

Success at entry-level hiring brings the new challenge of integrating these employees into the highly demanding work environment of human space flight. This is a task that has not existed in recent years. The OSF centers are taking various approaches. MSFC has designed a "Marshall Beginnings" that looks at leaders, activities, values, and the "New Employee Advocate Program" that assigns advocates (coaches) individually to new employees to provide guidance and advice. A pilot mentoring program will be expanded.

At JSC, an Individual Development Plan is being prepared for each entry-level hire. The emphasis is on acquiring hands-on experience in several of the engineering directorates. A new orientation program also has been developed. KSC has established a center-wide HR council, representing all major KSC workforce areas, to determine individual development opportunities. Fresh-outs also will be able to acquire hands-on experience through training partnerships with USA and other contractors. Each entry-level employee will be given a specific engineering project to complete within the first six months. Given these varying approaches, the Panel has recommended that an assessment be conducted to determine the relative success of these initiatives.

In addition to these integration and orientation activities, there is a growing need for advanced training of those hired to fill critical skills gaps, as well as to provide professional and career development opportunities. With the active encouragement of the NASA Administrator, the Agency is proposing to increase overall training resources by about 17 percent in fiscal year 2001 and by 50 percent in fiscal year 2002. Use of these resources, however, does not appear to be uniform by the OSF centers. The centers also report increased support for employees to acquire the Ph.D. degree.

In summary, the challenge no longer is trying to determine ways of making-do with a diminishing workforce. It is the equally demanding task of using newly acquired human resources most productively and in a manner that contributes solidly to NASA's future success.

## Computer Hardware/Software

Ref: Findings #14 and #15

The Software Independent Verification and Validation (IV&V) Facility was established in 1994 in Fairmont, West Virginia, to provide a center of expertise for independent analytical assessment of software for NASA missions. Management of the facility, initially centered at Headquarters, was subsequently transferred to the Ames Research Center (ARC). As part of the FY 2000 appropriation process, NASA was directed to:

- Achieve “substantial integration of the IV&V Facility into the NASA system”
- Take advantage of GSFC’s proximity to the IV&V Facility
- “...report, in conjunction with GSFC and no later than June 1, 2000, on what new activities the various NASA Centers are initiating with the IV&V Facility.”

In order to comply more fully with this directive, in March 2000, GSFC was directed to develop a Business Plan that included the transition of the Facility from ARC to GSFC management. This included a new and stronger interpretation of the requirements for IV&V. Each project is now required to produce and document a plan that addresses its software assurance over the life cycle of its software design and development. IV&V of software must be included when deemed appropriate based on project cost, size, complexity, life span, risk, and consequences of failure. The IV&V Facility was given responsibility for the management of all software IV&V within the Agency.

With the pervasiveness of software in current technology of all kinds, nearly every project and program manager will be impacted by this requirement. While IV&V can be very important to projects, proper utilization of it requires careful and early project and budget planning. Budgetary and organizational problems often arise when one tries to “shoe horn” IV&V in after a project is well under way, especially when an external organization at a remote location is involved. However, software development, and especially IV&V, processes are relatively new, and few program and project managers are familiar with them. Most managers simply do not have the training or experience to appreciate the issues and benefits involved. If NASA is to be successful in its endeavor to institute wide use of IV&V, proper software assurance training of management at all levels is necessary.

Of concern to the Panel is the possibility that the Facility will have to assume an enforcement role. If so, it could engender resentment from other NASA entities and make the task of incorporating IV&V into projects even more difficult.

The primary focus of the Facility’s activities will be on applying independent verification and validation (V&V) to projects. Only a small part

of the Facility's budget is directed toward research on new V&V techniques. For example, the increasing need for autonomous systems for long term and remote missions leads to the use of artificial intelligence approaches, such as neural nets and expert systems. Good techniques for V&V of such systems have not yet been developed. There is also a need to research improved techniques for evaluating the effectiveness of various software development and V&V approaches.

At present, there has not been a focused call for research activities. Rather, proposals have been accepted ad hoc and reviewed primarily internally. With the separation of the Facility from ARC, a research center, care must be taken to ensure that there is a strong research program focused on important problems. A long-term plan with adequate funding is needed.

## Ref: Finding #16

Due to numerous attacks by computer hackers, the need for computer security has risen to a high level throughout our society. NASA is no exception and has initiated a number of actions to address this problem. The activities instituted include: 1) an Agencywide security training program; 2) a self-evaluation of computer security at all centers; 3) a requirement that security plans be developed for all computer systems; and 4) use of a private key infrastructure (PKI) system for all of its computer communication. In addition, NASA has retained a private firm to evaluate computer security at its centers and run penetration tests to ascertain the resilience of its critical systems to hostile penetrations.

In many respects, NASA has made good progress on security plans. Security training is proceeding more or less on schedule, and the security contractor has completed its evaluation and penetration testing of three centers with good results. However, progress in two areas has been lagging. Problems have arisen with the PKI effort, and NASA has been unable to deploy the system as expected. NASA has been working with the vendor for a number of months, but problems remain. Second, while several NASA centers have completed their computer security plans, a number of other NASA centers have not made much progress.

In terms of operations, it is required that a computer security official be appointed for each major computer system. It appears that the computer security duties often are added to those of the systems administrators. There is concern that these extra duties are not always adequately recognized and rewarded. Also, there is a need to ensure that the security officers are adequately trained in the techniques and importance of their security role.

While NASA has a strong focus on computer security at this time, security must be an ongoing effort. There have been a substantial number of hostile attacks during the past year. Such will always be the case. Thus, computer security cannot be a one time crash effort. It must be an ongoing activity that continually examines NASA's systems and potential threats, improves security, and maintains continuing employee training.



## Ref: Finding #17

The Software Engineering Institute's (SEI) *Capability Maturity Model* (CMM) is based on the premise that the quality of software is highly influenced by the quality of the processes that are used to develop it. CMM is a five-level model that gauges the extent to which processes are explicitly defined, managed, measured, controlled, and used to improve software and the way it is developed. The five levels define the five stages through which organizations pass as they evolve their software processes. CMM was introduced in the late 1980s, and has become widely used throughout the world as a measure of an organization's ability to develop and deliver quality software.

There are 18 key process areas that are used to define the five levels in the Software CMM. Each key process area contains goals and best practices for achieving those goals. The levels range from 1 (lowest) with poorly defined processes, schedule slips, and cost overruns to level 5 (highest) with a quantitative characterization of all software processes, a focus on measurable software process improvement, and results that are highly predictable. The levels and their primary foci are:

**Level 1.** Focus is on competent people who can “save the day.”

**Level 2.** Focus is on basic project management of six key process areas: requirements management, project planning, project tracking and oversight, subcontractor management, quality assurance, and configuration management. Plans are based on past experience and results are generally repeatable.

**Level 3.** Focus is on process standardization in seven key process areas. The key process areas are: establishing organizational responsibility for improving overall software process capability; developing products and defining standard processes for improving performance across projects; developing appropriate skills through training; integrating software engineering and management activities; defining a product engineering process for producing correct, consistent software products; coordinating and integrating all contributing groups for improving customer satisfaction; and conducting peer reviews for detecting defects early in the development cycle.

**Level 4.** Focus is on quantitative management. Key process areas are measuring and controlling performance of the processes used by the software project and developing a quantitative characterization of the project's software product to achieve quality goals.

**Level 5.** Focus is on continuous process improvement. Key process areas are preventing defects by identifying and eliminating root causes, identifying and transitioning to new technologies that improve processes, and continually evolving software processes to enhance quality, increase productivity, and decrease cycle time.

At the end of 1999, more than 75 percent of the 870 commercial and government organizations that had reported their Maturity Level to the SEI

during a 5-year period were at Level 1 and 2, more than 17 percent were at Level 3, just under 5 percent at level 4, and only 1.8 percent had achieved Level 5. Approximately half of these organizations were government agency/military and related contractors.

## Ref: Finding #18

The Multiplexer/Demultiplexers (MDMs) are the principal computers of the ISS. They are based upon Intel 386 processors and utilize a 16-bit backplane. They also have limited memory by today's standards. The raw computing power of the 386 processors is more than an order of magnitude less than current state-of-the-art processors. The use of a 16-bit bus reduces throughput of memory accesses by at least a factor of two. This latter point is particularly important with respect to input/output operations via a separate processor with which the MDM communicates over the bus. As the MDMs are the central core of ISS operations, they are safety and mission critical components.

The software running on the MDMs involves several different tasks. Scheduling the execution of these tasks in a manner that assures that all tasks get done on time is a problem that generally becomes increasingly difficult as the utilization of the central processor unit (CPU) increases. The requirements for ISS specify that the CPU utilization of the MDMs should be no more than 65 percent. Although a reasonable requirement, it is proving difficult to achieve.

Throughout the development history of the ISS software, the utilization of the MDMs has been a concern. Recently, utilization problems surfaced during MEIT testing. NASA was able to do some clever reprogramming to eliminate this particular problem. However, at present the MDM CPU utilization is already at 65 percent. Four major deliveries of ISS software remain, each of which is expected to significantly increase the CPU utilization. At present, NASA's primary strategy for handling these increases that will put utilization far above the 65 percent requirement is to depend upon developing code optimizations to reduce the CPU utilization. There is no guarantee this approach will succeed.

A long-term approach to the MDM limitations is to upgrade the CPU to a current generation Pentium processor. A contract was awarded to evaluate the possibility of a CPU upgrade, and a report was received in early fall 2000. However, NASA is not pursuing any follow-on activity at this time. In view of the growing CPU utilization and the likelihood of increased demands over the life of the ISS, NASA needs to continue to pursue an upgrade to the MDMs as rapidly as possible. With this effort, it is important to consider not only the CPU but also the bus structure.

## Extravehicular Activity (EVA) and Radiation Protection

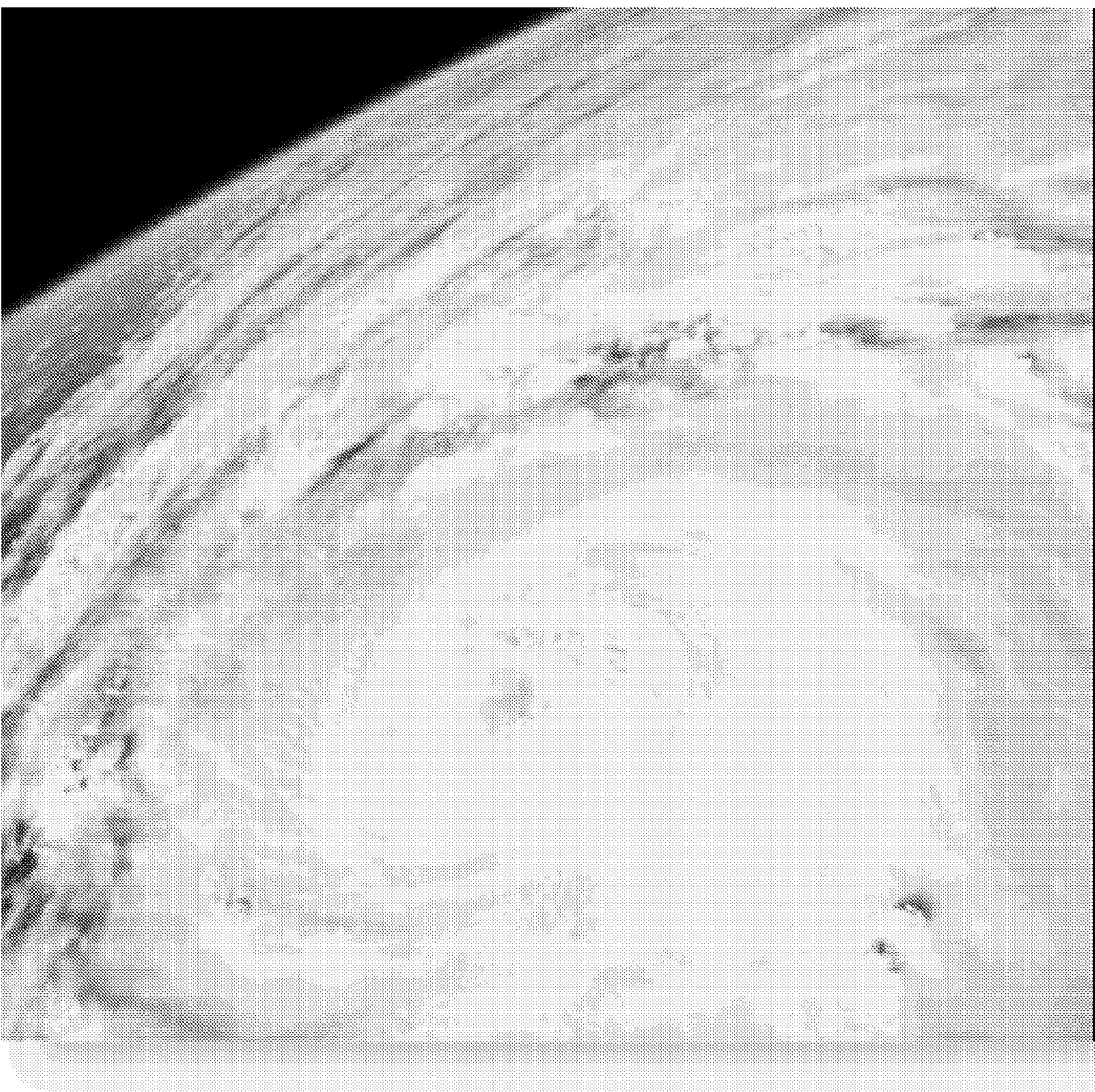
Ref: Finding #19

For ISS astronauts, the highest percentage of radiation exposure to the organs will be from Galactic Cosmic Radiation (GCR), including neutrons. Limitations in the operational effectiveness of neutron detectors have restricted the ability to characterize neutron spectra and dosage. For near-term ISS and Space Shuttle crews, accurate monitoring is essential to the understanding of radiobiological effects, in the design of shielding and development of operational improvements, and in organ dose projections for career records and planning. The requirement will become even more critical as humans venture into deep space.

## Ref: Finding #20

The current EMU is expensive to maintain, unwieldy, deficient in providing radiation protection, mechanically complex, not optimized for the incorporation of advanced technologies, and operationally limited. Utilizing the expertise of U.S. domestic suppliers and technology that might be available from international partners, a comprehensive program could produce a next generation space suit in about six years.

## appendices



# Appendix A

## AEROSPACE SAFETY ADVISORY

### PANEL MEMBERSHIP

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## Appendix B

### NASA RESPONSE TO ANNUAL REPORT FOR 1999

#### SUMMARY

NASA responded on August 16, 2000, to the "Findings and Recommendations" from the *1999 Aerospace Safety Advisory Panel Annual Report*. NASA's response to each report item is categorized by the Panel as "open, continuing, or closed." Open items are those on which the Panel differs with the NASA response in one or more respects. They are typically addressed by a new finding, recommendation, or observation in this report. Continuing items involve concerns that are an inherent part of NASA operations or have not progressed sufficiently to permit a final determination by the Panel. These will remain a focus of the Panel's activities during 2001. Items considered answered adequately are deemed closed.

Based on the Panel's review of the NASA response and the information gathered during the 2000 period, the status of the recommendations made in the *1999 Aerospace Safety Advisory Panel Annual Report* is presented on the following pages.

***Finding and Recommendation # 1: Continuing*** - Although NASA has totally turned around its workforce policy for OSF centers, the gaps in critical skills, stress, and schedule pressures will remain until new workforce additions are trained, integrated, and performing at high levels. In addition, retention of critical skills is a continuing problem as employees retire or seek greener pastures. Although NASA has resumed hiring, continuing attrition has resulted in a low net gain of personnel.

***Finding and Recommendation # 2: Continuing*** - NASA correctly cites various new efforts to deal with the problem, but challenges remain. Experienced employees in functional directorates have been hesitant to transfer their critical skills to the Space Shuttle and ISS programs, although this problem appears to be less severe than it was a half-year ago. More attractive incentives may be appropriate. Some NASA centers continue to report the limited impact of HQ-driven training initiatives. NASA-contractor training partnerships need to be assessed.

***Finding/Recommendation #3: Continuing*** - The effort is off to a good start in concept as evidenced by the video "Success in Process Control," but evidence is needed that the renewed attention gets down to subcontractors and vendors. Some NASA established benchmarks would enable a measure of results.

***Finding/Recommendation #4: Continuing*** - Good start but it's a major undertaking with a long way yet to go. Effort needs an agreed upon measure of effectiveness in order to judge success.

***Finding/Recommendation #5: Continuing*** - NASA reports the beginning of a plan, but it's incomplete and funds have yet to be identified.

***Finding/Recommendation #6: Continuing*** - Hiring is underway, but numbers are not up to requirements just yet and KSC is now in an era of higher flight rates. Far too early to close the issue.

***Finding/Recommendation #7: Continuing*** - NASA's response is encouraging but more information is needed on how widespread these efforts are.

***Finding/Recommendation #8: Closed*** - A satisfactory response.

***Finding/Recommendation #9: Closed*** - A comprehensive response.

***Finding/Recommendation #10: Closed*** - The Joint NASA-RSA Team has certified the modified Russian Solid Fuel Oxygen Generator (SFOG) for service in the ISS. NASA also has a certified "off-the-shelf" unit ready for service.

***Finding/Recommendation #11: Closed*** - A satisfactory response.

***Finding/Recommendation #12: Closed*** - The next generation space suit is the subject of a new item for the 2000 Annual Report.

***Finding/Recommendation # 13: Closed*** - A satisfactory response.

***Finding/Recommendation # 14: Continuing*** - While the intent expressed is in accord with the recommendation, it is the completion of the present work that will fully respond to the item.

***Finding/Recommendation # 15: Continuing*** - NASA's security program is moving in the right direction. However, it has a long way to go before it is complete.

***Finding/Recommendation # 16: Continuing*** - NASA is moving in the direction of funding the upgrades, but the final commitments have not yet been made on the category of upgrades addressed.

***Finding/Recommendation # 17: Closed*** - A satisfactory response.

***Finding/Recommendation # 18: Closed*** - A satisfactory response.

***Finding/Recommendation #19: Closed*** - This response is adequate assuming the programs referenced are actually continued.

***Finding/Recommendation # 20: Continuing*** - A new finding on the subject is included in the current report.

***Finding/Recommendation #21: Closed*** - A satisfactory response.

***Finding/Recommendation #22: Closed*** - The NASA response is adequate.

***Finding/Recommendation #23: Closed*** - The response is acceptable.

***Finding/Recommendation #24: Closed*** - A sufficient response.

National Aeronautics and  
Space Administration  
**Office of the Administrator**  
Washington, DC 20546-0001



AUG 16 2000

Mr. Richard D. Blomberg  
Chairman  
Aerospace Safety Advisory Panel  
1010 Summer Street  
Stamford, CT 06905-5503

Dear Mr. Blomberg:

In accordance with your request after our February 10, 2000, meeting, enclosed is NASA's response to Section II, "Findings and Recommendations," from the Aerospace Safety Advisory Panel (ASAP) Annual Report for 1999.

The ASAP's efforts in assisting NASA to maintain the highest possible safety standards are commendable. Your recommendations are highly regarded and continue to play an important role in risk reduction in NASA programs.

We thank you and your Panel members and consultants for your valuable contributions. ASAP recommendations receive the full attention of NASA senior management. In particular, I expect that NASA's Office of Safety and Mission Assurance will track resolution of these issues as part of their role in independent assessment.

We welcome the continuance of this beneficial working relationship with the Panel.

Sincerely,

A handwritten signature in dark ink, appearing to read "Daniel S. Goldin", written over a horizontal line.

Daniel S. Goldin  
Administrator

Enclosure

# 1999 Aerospace Safety Advisory

## Panel (ASAP) Report

### Findings, Recommendations, and Responses

#### WORKFORCE

##### Finding #1

The continuing downsizing at Office of Space Flight Field Centers, coupled with the effects of the prior hiring freeze and unplanned departures, has produced critical skills deficits in some areas, growing workload pressure and stress levels, and a serious shortfall of younger S&Es.

##### Recommendation #1

NASA must continue to address workforce problems aggressively and establish program priorities that ensure a workforce capable of achieving long-term safe and effective operations. Emphasis should be placed on eliminating critical skills shortfalls and recruiting younger S&Es who can develop into experienced and skilled future leaders.

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appendices

##### Response

NASA concurs with the ASAP recommendation. As a result of the ASAP findings and recommendations, as well as other external and internal reviews of the workforce, NASA has terminated downsizing at the Office of Space Flight (OSF) Centers. All four OSF Centers—the Johnson Space Center (JSC), Kennedy Space Center (KSC), the Marshall Space Flight Center (MSFC), and the Stennis Space Center (SSC)—are in the midst of large-scale efforts to replace skill losses and increase the number of entry-level professionals. NASA has a plan in place to hire close to 600 new employees in fiscal year (FY) 2000 that will fill some of our most critical skill shortages and enable us to begin efforts to rebuild our cadre of future leaders. These new critical staff hires are designed to support program requirements for Space Shuttle Operations and Upgrades, Space Station Development and Operations, Expendable Launch Vehicles, Advanced Space Transportation Technology and other Center mission-related and administrative requirements. The hiring of these new employees is geared to alleviating stress impacts resulting from expanding workload pressures coupled with continuous downsizing; eliminating critical skill shortages across our programs and Centers; and pursuing fresh-out hires to revitalize our Science and Engineering (S&E) knowledge base for future program and project management responsibilities. In addition, NASA is

seeking to refocus our workforce composition towards a future-oriented research and development base. Specific short-term scientific and engineering expertise or operations-oriented requirements will be satisfied by utilizing nonpermanent term appointments and Intergovernmental Personnel Act assignments. In addition, we anticipate the ability to replace upcoming losses on a one-for-one basis in the years to come.

Our hiring capability has sparked renewed enthusiasm throughout JSC, KSC, and MSFC, and SSC. Employees and managers are eager to return to a time when NASA had a continuing influx of the best and brightest graduates in the engineering and science fields. We have carefully planned our recruiting strategy to ensure success in achieving this goal. To this end, we have identified critical skill shortages and made them our top hiring priorities. We have established a goal of hiring 50 to 70 percent of new personnel at the entry level in an effort to revitalize our workforce with high-caliber, recent graduates.

NASA's recruiting efforts are aimed at some of the top engineering and business schools in the country, including minority universities. We have involved many NASA employees in our recruiting initiative by sending them to conduct on-campus interviews with potential candidates. The OSF Centers' rigorous screening process requires that potential employees possess degrees that are consistent with long-term needs, a minimum grade point average of 3.0 (on a 4.0 scale), outstanding references and other indicators of high achievement (e.g., extracurricular activities, honor society membership, community involvement, and awards). We are already seeing hiring results that are on track for meeting these goals.

Finally, the contractor workforce will be enhanced, where appropriate, for maintaining safe and effective operations. An example of this is the United Space Alliance (USA) initiative to enhance work documentation with new technology and off-the-shelf products and still maintain increased flight-rate capability.

## Finding #2

The combination of downsizing losses, hiring restrictions, and transition of responsibilities from NASA to contractors, such as USA, continues to limit the opportunities for junior and mid-level NASA managers to gain the operational knowledge and experience required for continued leadership in senior management positions.

## Recommendation #2

Innovative arrangements between NASA and its contractors to provide entry-level and mid-level NASA S&Es with operational, “hands-on” experience should be strengthened and expanded. Project management training initiatives, such as the Academy of Program & Project Leadership (APPL), must strive to broaden their outreach to management teams and individuals at Field Centers.

## Response

NASA concurs with the ASAP recommendation. NASA agrees that its existing programs and initiatives should be intensified and broadened to provide opportunities for hands-on work experiences, not only for new hires, but also for all career levels. Providing a broad set of work experiences is key to building leadership capability, and NASA has a number of programs in place or in development that will improve our capability to do so. Examples include:

- co-op assignments partnered with contractor systems engineers
- direct observation or procedure review of critical tasks
- management of Shuttle launch countdown, launch, and landing/recovery
- participation in flight and ground systems development and enhancements
- processing mid-decks, utilization payloads, and partial Shuttle payloads
- participation in contractor testing, and anomaly resolution
- ensuring adequately designed, tested, and assembled hardware

To allow some of our best junior- and midlevel personnel the opportunity to broaden their functional experiences, the Space Shuttle Program Office has created rotational opportunities at several Centers where they can gain experience at the program level before considering a program office job. This early exposure to the significant operational and programmatic management challenges will better equip them to serve in future leadership roles in either a functional-, project- or program-level organization.

Our current hiring strategy also considers how to develop our leadership capability. Placing engineers fresh out of college into hands-on directorates (i.e., engineering, mission operations, etc.) allows the Agency to

move experienced personnel from these line organizations into jobs in the program offices where they can build on the experience base they bring from functional jobs.

Formal training opportunities have expanded in recent years. We take advantage of opportunities to bring courses to the Centers for intact work groups and will increase our use of intact team training and performance support tools in the future.

An example of a unique partnering relationship in the project management training area at JSC has been the Engineering Directorate's work with Lockheed Martin and the consulting firm of Kepner-Tregoe. Kepner-Tregoe designed a course specifically tailored to include the NASA process for the development of Government Furnished Equipment (GFE) hardware. Many of the Engineering Directorate's civil servant GFE project managers participated in sessions with their Lockheed Martin counterparts. This experience was extremely beneficial for all involved and can serve as a model for the future.

At the Agency level, our Academy of Program/Project Leadership provides developmental training opportunities for future and current program/project personnel and additionally provides a full curriculum of courses for personnel at all levels. The Academy includes 23 courses, performance support to intact teams, a project management assessment initiative, web-based tools for project managers, a knowledge management/best practices initiative, and a project management development competency model for developing personnel. We have initiated a new option for high performing potential project personnel which includes a 1-year development assignment and up to 2 years graduate study at MIT, which provides a dual masters degree in business and systems engineering.

Future directions in training and learning for the program and project management workforce will take us to using the latest advances in learning delivery methods and technology, providing team learning directly to project and organizational teams, providing individual training emphasizing technical and leadership core competencies and skills, and providing mentoring and coaching for program and project managers. We will emphasize and encourage continual learning in the workplace as well as academic training in these areas, and we will form alliances with our industry and Government partners, encouraging them to also foster similar continual learning efforts within their organizations. Through these efforts, NASA and its partners will achieve higher levels of skill in project management and leadership.



# SPACE SHUTTLE PROGRAM

## Finding #3

The Space Shuttle Program Office has instituted a set of Process Control Focus Groups whose goal is to implement “best practice” commonality in change control procedures across all supplier tiers.

## Recommendation #3

Focus the active and dedicated support of senior management of the major contractors and all their subcontractors on implementing the process control “best practices” as soon as feasible. NASA must be fully apprised of all process changes even if they result in a product that meets requirements.

## Response

NASA concurs with the recommendation. The Government and Industry Process Control Focus Group has been established by the Manager, Space Shuttle Program (SSP), and is aggressively developing a coordinated and consistent process control program for the SSP. The goal of the Process Control Focus Group is to achieve common process change control across all program elements. A Process Control Management Plan has been developed with formal sign-off by NASA and all prime contractors required. Membership of this group includes civil servant representation from JSC, KSC, and MSFC and all the Space Shuttle prime contractors. The efforts of this group are focused on increasing communication of the importance of process change control to all elements of the program including subtier suppliers, implementation of best practices, and sharing lessons learned among all Shuttle contractors.

To increase awareness of the SSP emphasis on process control, increased communication with the suppliers will be accomplished by several methods, including an SSP Process Control video, posters, and brochures. These are examples of tools that will be used during motivational visits to suppliers by prime contractor and SSP management.

A process control best practices and lessons learned database is being developed by the focus group for use by NASA and the prime contractors to share lessons learned and implement the use of best practices across the program. This database will include the process/product integrity audits and process failure mode and effects analyses (FMEA) mentioned in the ASAP report as good process control techniques. Symposiums to share in-depth techniques for applying these best practices to different business situations are also planned. In summary, establishment of the focus group, development of the database, use of a process control video

and other tools during NASA and contractor management motivational visits to suppliers, and the utilization of symposiums will foster NASA process change awareness and focus the major contractors and their sub-contractors on implementation of best practices process control.

## Finding #4

Although progress has been made to improve the quality, accuracy, and traceability of the work instructions (“paperwork” used in the processing of Space Shuttle Orbiters) much remains to be done to provide correct and unambiguous procedures. There are still too many unincorporated changes.

## Recommendation #4

Efforts to improve the quality, accuracy, and traceability of the work paper as well as the timeliness of incorporation of changes to work instructions must be given higher priority by both NASA and USA in a coordinated, systematic effort.

## Response

NASA concurs with the ASAP recommendation. During the 1999 calendar year, numerous initiatives were accomplished which established the foundation to improve the quality, accuracy, and traceability of work instructions. Examples of these initiatives include appointment of a USA documentation manager and four dedicated project leads, the creation of a new work instruction format and style guide, development of a systematic procedure to perform task and document analysis, development of the new work authorization document authoring and validation environment (WAVE) computer software to allow engineers to quickly and easily modify work instructions, and reduction of deviation backlog. With this foundation, priority was given by USA shuttle engineering to establishing a Year 2000 Strategic Initiative to “Increase the quality and level of workability of work-authorizing documentation.” In addition, a comprehensive Category I Document Evaluation & Restructure (CDER) Plan was established to effectively improve the quality, accuracy, and tractability of both flight and groundwork instructions.

The CDER Plan will ensure document simplification as the WAVE software, Maximo, and PeopleSoft initiatives are implemented. Work instructions, rewritten to the new standards established in 1999, will include restructuring to only include the work steps needed for that specific task as defined by the needs of the Maximo Job Plan and PeopleSoft Product Structure. Contingency steps, or steps applicable to other hardware, will be removed and placed in a separate work instruction package to avoid confusion. Also, work instructions that could be in multiple formats due to numerous previous contractor requirements will be converted to standard formats. Finally, any existing deviations will be incorporated as part of the rewrite. The end result will be a smaller, cleaner, concise work instruction package, including more graphics and pictures. The procedures will be reviewed and agreed to by the end user. This plan has two primary paths—one for flight operations and another for ground operations. The determination of which of these paths a work instruction will follow is

dependent on the criteria set forth in the PeopleSoft Product Structure and the Maximo Job Plan. PeopleSoft and Maximo are management systems through which a reduction in the time required to incorporate paper-work can be achieved.

The conversion of documents to PeopleSoft and Maximo will be heavily site and flow dependent. The goal is to complete approximately 500 planned flight hardware processing work instructions for calendar year 2000, with continued emphasis in subsequent years. Selection of those work instructions is based on pre-established criteria involving run frequency and criticality. By the end of FY 1999, USA had reduced deviations approximately 25 percent, from 7,300 to 5,535. A technical standard panel has been implemented and is chartered to review errors detected by audit teams, determine the root cause of the discrepancies, and take real-time action to prevent their re-occurrence.

Also, the implementation of a distributed authoring approach allows engineers to write their work instructions, provide ownership, control and accountability of their work instructions, and increase the number of operational maintenance instructions with zero deviations. To allow the engineer to make quick and easy incorporation of changes and provide on-line review and concurrence by USA and NASA prior to the work instruction being issued to processing operations, a single Universal Test Operations Procedure format has been established for all flight documents in Documentum/PeopleSoft, and a single Job Plan format has been developed for all ground documents in Maximo. A standard electronic deviation template has also been developed. These actions will assure succinct, technically accurate, and user-friendly work instructions.

## Finding #5

There is no systematic plan to counter obsolescence and assure the availability of adequate facilities, GSE, and specialized test-and-checkout equipment throughout the expected lifetime of the Space Shuttle.

## Recommendation #5

Develop and execute a plan to ensure that all needed support and test-and-checkout facilities and equipment are assured available and protected from obsolescence for the maximum foreseeable life of the Space Shuttle.

## Response

NASA concurs with the ASAP recommendation. A specific focus on SSP infrastructure has been established for FY 2000, identifying issues and concerns throughout the program. The SSP initiated an effort in November 1999 to develop a plan and identify the requirements and resource levels required to address the infrastructure backlog and supportability needs for the SSP through FY 2012. This effort has incorporated all SSP elements and support functions at Office of Space Flight Centers and the Dryden Flight Research Center. The completed plan will define infrastructure project funding requirements for vital components that support or directly impact the SSP. The plan spans across multiple years and will address the SSP short-term as well as long-range needs. Supporting SSP element infrastructure long-range assessments/plans have been completed or are in the process of completion. Two examples of SSP element supporting efforts are the Ground Systems Survivability Assessment, which addresses obsolescence by providing a component level assessment of requirements to maintain or improve existing capabilities, and the External Tank Project's 15-year plan. The completion of the Infrastructure Plan is a major Space Shuttle initiative whose results will be included in the Program Operating Plan strategy. The SSP has assigned a lead at KSC to formulate the SSP infrastructures upgrades requirements.

## Finding #6

Space Shuttle processing workload is sufficiently high that it is unrealistic to depend on the current staff to support higher flight rates and simultaneously develop productivity improvements to compensate for reduced head counts. NASA and USA cannot depend solely on improved productivity to meet increasing launch demands.

## Recommendation #6

Hire additional personnel and support them with adequate training.

## Response

NASA concurs with the ASAP recommendation. Both NASA and USA recognize the need to assure adequately staffed and trained personnel for processing the Shuttle and, simultaneously, pursue productivity improvements that can help meet the planned flight-rate increases. To address this concern, KSC civil servant Shuttle Processing has authorization for additional staff, and USA is increasing their workforce at KSC from 3,650 to approximately 3,900 to support Shuttle processing. Recruitment for these positions is in progress and expected to be completed in FY 2000. Finally, a replenishment rate for FY 2001 has been authorized at KSC, which will permit continued infusion of skills to offset anticipated attrition.

## Finding #7

Due to attrition of experienced personnel, NASA and its contractors are assigning more newly trained personnel to Space Shuttle operations tasks. This has led to concerns in the workforce regarding the qualifications of some newly-assigned personnel.

## Recommendation #7

NASA and its contractors must ensure that their training, certification, and task assignment processes are such that only suitably qualified engineering and technical personnel are performing Space Shuttle operations. Any training and licensing program to certify new personnel must include both testing of acquired skills and demonstrated proficiency on the assigned task.

## Response

NASA concurs with the ASAP recommendation. NASA and the contractor agree that demonstrated proficiency for operational tasks is a key factor to safety and success. NASA and the contractor recognize the direct relationship between personnel proficiency and flight safety, and this is reflected in the training, certification, and operator assignment processes implemented by both NASA and contractor. For ground operations involved in processing and operating the Space Shuttle systems, all newly hired contractor personnel are provided applicable training for security, safety, and the critical skills required for the area and system of their assignment. In addition to this general training, contractor personnel begin their orientation by becoming familiar with procedures, drawings, physical surroundings, etc. Once they have an understanding of these requirements, they accompany other experienced, skilled personnel on the job performing formal and informal on-the-job-training (OJT).

In addition to the certification provided upon the successful completion of OJT, engineers must also complete Stand Board examinations for critical systems. Processing tasks are assigned based on the experience level of the employee. Processing tasks are not all equally critical, and newly-certified personnel are generally assigned to low criticality tasks. This allows the more experienced personnel to focus on critical tasks. Employees are required to be recertified on a regular basis. The recertification involves varying degrees of proficiency testing based on the functional criticality of the task.

The concerns and needs for assuring that the contractor workforce has the appropriate skills and proficiency to perform Space Shuttle processing responsibilities are applicable to the NASA civil service workforce as well. Training plans are defined for all entry-level technical positions within NASA Shuttle Processing. These plans include both formal classroom training and OJT packages required for the performance of the NASA

Space Shuttle operations role. Newly-hired or transferred personnel are required to accomplish this training prior to performing unsupervised engineering or technical tasks. The supervisor is responsible for assuring that the training has been accomplished and adequate proficiency has been demonstrated. There is also continuous involvement with critical task surveillance, out-of-family disposition, and NASA-retained functions to maintain the critical skills of the workforce. While the level of direct NASA involvement has decreased with the planned transition of more responsibility to the contractor, NASA Shuttle Processing has increased its focus on simulation training to augment the need for engineers to maintain their knowledge of systems performance and operations. Increased utilization of Tier 3 training (integrated simulation training) has been implemented. Tier 1 (single system) and Tier 2 (multisystem) simulation training is also being planned to ensure proficiency. Requirements definition for system development is now complete for Tier 1/Tier 2 training, and implementation plans are in work.

In the flight operations area of Space Shuttle support, the Mission Operations Directorate and USA have jointly defined and documented training and certification criteria for all personnel assigned to mission-critical functions. These plans are based on the position requirements and criticality of the assigned position. The training and certification plans and processes are unique for flight designers, training instructors, and flight controllers. Personnel are not assigned mission-critical responsibilities without having executed formal training and certification plans, as well as successfully demonstrating the capabilities consistent with the level of responsibility required by the position. Extensive use of simulations for mission control teams and individual operators is used in both the initial certification and the continuous proficiency training of flight control operators. Experience level is a critical part of successful flight operations. To ensure that training, certification, and task assignment processes are such that only qualified personnel are performing Space Shuttle operations, NASA uses trending and root-cause analysis of quality and safety occurrences to indicate those traceable to training processes. This approach allows for a continuous assessment of the process of providing qualified personnel for performance of Shuttle processing and operations.

USA has a performance management program to: 1) Ensure communication between the employee and management; 2) Ensure that responsibilities and expectations are clearly understood; 3) Review employee job performance; 4) Make recommendations to improve employee job performance; and 5) Establish a record of the performance achieved by each employee. This performance management program is an ongoing process of planning, coaching, and reviewing. Management meets with each employee to discuss and establish individual objectives, including training, each year, and agree on how employee success will be measured.



# INTERNATIONAL SPACE STATION (ISS) PROGRAM

## Finding #8

Acquisition of the ISS Crew Return Vehicle (CRV) has been lagging and appears to be facing further delay. The full-crew CRV is needed for long-term safe operation of the ISS with a crew larger than three astronauts.

## Recommendation #8

Take whatever steps are necessary to halt the delays to the CRV program without jeopardizing adequate demonstration of safety of design and certification of human-rating.

## Response

NASA concurs with the ASAP recommendation. Significant progress has been made in establishing the CRV project in the last year due to commitment at all levels within NASA - from the Administrator, the Office of Space Flight, JSC, the ISS Program Office, and the X-38/CRV Project Office. The original Office of Management and Budget (OMB) decision and Congressional markup reduced the project funding in FY 2000, which delayed the start of CRV Phase 1 (engineering development through critical design review). NASA Headquarters successfully argued for the necessity of starting Phase 1 in FY 2000 and obtained OMB concurrence to transfer funding to start this phase in late FY 2000.

The request for proposals for CRV Phase 1 has been released since the last ASAP review. Bids have been received from three offerors and are currently being evaluated. The current evaluation schedule will allow a Phase 1 contract award in the August-September 2000 timeframe, and the funding is in place.

In support of this planned CRV Phase 1 start, the X-38 Project Office has worked with the Langley Research Center (LaRC), Independent Program Assessment Office, to close out all open actions from the LaRC independent assessment (IA). Approximately 90 percent of the 110 "maturity gates" identified by the IA team have been closed to date, and an acceptable status of all of the 110 items is expected prior to a final Headquarters Program Management Council presentation in July 2000. Progress on these items confirms a significant reduction in risk prior to the start of Phase 1.

The X-38/CRV prototype project has successfully completed five atmospheric flight tests and numerous parafoil tests. A major milestone was achieved in January 2000, with the first flight test of the full-scale parafoil

for the space vehicle. This parafoil is the size necessary for a CRV carrying seven crewmembers and contains all required design features for a human-rated system. This test was conducted without any anomalies, demonstrating NASA's clear understanding of all the basic technical issues of parafoil flight as well as our ability to extrapolate from sub-scale testing to full-scale testing. The atmospheric vehicle flight tests have demonstrated many of the new technologies (lifting-body aerodynamics, flight control systems, parafoil deployment, and electromechanical actuators) planned for the CRV. A fifth test is scheduled prior to the end of July 2000, which will confirm performance characteristics of the improved body shape. In addition, the critical element in the CRV navigation system will be tested in space aboard the Space Shuttle on STS-101 in May 2000. A critical CRV technology - global positioning system-based attitude determination - will be demonstrated on this flight. In the aggregate, all of these tests significantly reduce the technology risks of the CRV.

Assembly and testing of the X-38 space test vehicle is proceeding, and the first simplex power-up to the vehicle occurred in March 2000, verifying end-to-end system power. The Space Shuttle program is currently manifesting the X-38 space test for April 2002. This will support a start of CRV Phase 2 (production) at the start of FY 2003, and a CRV operational date in late FY 2005 to early FY 2006, based on final production funding profiles.

NASA remains firm in its commitment to review results from the space test prior to production. NASA has further established decision logic to be used to determine if a space test of the production vehicle will be necessary after the X-38 space test. This decision logic will ensure that critical evaluation and testing are not compromised by the accelerated CRV schedule.

## Finding #9

The NASA personnel who are involved in finding solutions for the problems of radiation in space have developed an excellent long-range plan to define approaches for crew protection.

## Recommendation #9

Continue to support the nascent, but better defined, radiation effects research and development program.

## Response

NASA concurs with the ASAP recommendation. NASA has focused on solutions for the radiation program. Our recommendations include: (1) Completing and expanding on efforts made in the May 1999 EVA Radiation Protection Summit held at JSC to improve radiation protection. This involves development of an active personnel dosimeter to be worn on the extravehicular mobility unit (EMU) (first test flight to be in Fall of 2000), study of possible shielding improvements for EMU and design of localized shielding enhancements to ISS, and development of trapped radiation models; (2) Increasing coordination between NASA's Office of Life and Microgravity Sciences and Applications, the JSC Radiation Health Program, the National Oceanic and Atmospheric Administration (NOAA), and NASA's Office of Space Science on forecasting and monitoring changes in space weather; and (3) Improving coordination of radiation protection across NASA. To further the coordination across NASA, Dr. Richard Williams, from NASA Headquarters, Office of Life and Microgravity Sciences and Applications, has been appointed as head of a task group to develop an Agencywide plan to implement this objective.

## Finding #10

The Russian Solid Fuel Oxygen Generator (SFOG) is baselined as the backup oxygen supply system for the ISS. This device has experienced problems in its application on Mir and thus may be a potential safety hazard when operated on the ISS.

## Recommendation #10

Examine ways to eliminate the risks posed by the use of the Russian SFOG such as by determining the availability of a better, "off-the-shelf," safety-proven SFOG or by initiating an R&D effort to produce a safer alternative.

## Response

NASA concurs with the ASAP recommendation. A joint NASA-Russian Space Agency (RSA) team has completed an investigation of the SFOG experience on Mir. The failure mode has been identified and has been reproduced and verified during ground tests. The position of the NASA-RSA team is that the Mir experience was an isolated incident. Units planned for use on the ISS have been subjected to lot testing and screening of manufacturing and quality records and test reports. A non-flammable containment system to prevent propagation of a fire has been developed and tested as an additional safety enhancement. The conclusion of a joint NASA-RSA engineering, safety and mission assurance, and program management team is that this system is safe for operation on the ISS.

A parallel effort to develop a commercial off-the-shelf oxygen generation system was initiated by NASA during the SFOG failure investigation. This system has been certified for use, if necessary.

## EXTRAVEHICULAR ACTIVITY (EVA)

### Finding #11

The EVA Project Office has several planned initiatives to ensure the availability of adequate EVA resources to support the ISS and Space Shuttle. These initiatives cover acquisition of material, development of procedures, and improved training.

### Recommendation #11

Expedite completion of the planned initiatives related to the safety of EVA so that maximum benefit can be realized during the upcoming intensive ISS assembly schedule.

### Response

NASA concurs with the ASAP recommendation. In June 1999, the EVA Project Office initiated the development of a small planar hard upper torso (HUT) in addition to the medium, large, and extra-large HUTs already developed. With four HUT sizes, the broadest range of crewmembers (~5<sup>th</sup> percentile Asian female to 95<sup>th</sup> percentile Caucasian male) will be accommodated. The small planar HUT has successfully completed the concept development phase, and the preliminary design review is scheduled for May 2000. The first flight item is on schedule for delivery in October 2002.

Redesign of the (EMU) to allow for on-orbit replacement of a primary life support subsystem, HUT, displays and control module, and secondary oxygen pack is ahead of schedule to support the ISS 6A flight. The EVA Project Office is assessing the feasibility of flying the EMU on-orbit replacement unit configuration on ISS flight 5A prior to the need to leave an EMU onboard the ISS during 6A.

Single mission certification for the phase VI glove was accomplished prior to ISS flights 2A and 2A.1. Full certification (up to 19 EVA's) was completed in March 2000, approximately 1 year prior to leaving phase VI gloves onboard the ISS for ~90-day increments.

Like the phase VI glove, the U.S. Simplified Aid for EVA Rescue (SAFER) has flown with single-mission certification on five previous missions. Anomalies identified during three of these previous missions - STS-86 (failed NASA standard initiator (NSI) drive circuit), STS-88 (erroneous indication of no remaining gaseous nitrogen), and STS-96 (inadvertent NSI firing) - have all been successfully resolved through hardware redesign and/or procedures modification. A final anomaly relative to the battery gauge, which supports the requirement to remain onorbit contin-

uously for 1 year, has been resolved, and the hardware will be certified prior to ISS flight 2A.2a (STS-101) in May 2000.

Development of the Russian SAFER (RSAFER) was transferred to the RSA in April 1999 when they offered to cost share the hardware production and successfully completed the project preliminary design review. Currently, the critical design review is planned for FY 2001. One open issue to be resolved is the contractual authority to develop the RSAFER. The original plan included the RSAFER in the \$35M contract modification between NASA and the RSA; however, due to congressional concerns this contract modification is currently on hold. The baseline plan to launch the RSAFER on ISS flight 7A.1 will need to be readdressed following official contract authority with the RSA.

Lastly, NASA has successfully completed all of the technical and medical work necessary to implement a 2-hour EVA prebreathe protocol from a 14.7 psi atmosphere. NASA Headquarters has given approval, and plans are being developed to demonstrate the 2-hour protocol procedures (either on the ground or as part of a detailed test objective demonstration on ISS flight 5A or 6A) prior to implementation on ISS flight 7A when the joint airlock is launched. Additionally, decompression sickness contingency plans and flight rules have been developed, and crew and flight surgeon training has been initiated.

## Finding #12

The funding of the EVA R&T program is not adequate to provide the maximum safety benefit in terms of new equipment and procedures that lower the risk of extravehicular activities.

## Recommendation #12

Fund a robust EVA R&T program.

## Response

NASA concurs with the ASAP recommendation. The EVA Project Office maintains the EVA technology roadmap defining critical and pacing technologies for future advancements. Each year, in the budget process, the EVA Project Office makes recommendations to the benefiting programs when it is prudent to pursue research and technology. In FY 1999, due to hardware obsolescence, the Space Shuttle Program approved the redesign of the EMU caution and warning system. Additionally, in FY 2000, the EVA Project Office is assessing the need to redesign the EMU displays and control module, also for hardware obsolescence reasons. Long-term cost savings (through FY 2020) may be possible with new spacesuit elements, and perhaps even a new spacesuit, rather than maintaining the current design.

## COMPUTER HARDWARE/SOFTWARE

### Finding #13

NASA has taken positive steps for upgrading security on the ISS uplink by adopting a more robust encryption scheme. The downlink and the links between the Mission Control Centers (MCCs) in Houston and Moscow, however, are not encoded.

### Recommendation #13

Conduct an overall threat analysis of the Space Station downlink and its interfaces to both MCC Houston and MCC Moscow.

### Response

NASA concurs with the ASAP recommendation. The ISS uplink is critical to the safety of the ISS and contains encryption and processing safeguards to ensure that it is protected. Automated commanding will not be downlinked. If the downlink were compromised, the result would be momentary transmission of erroneous data to flight controllers, who would resolve the erroneous data prior to responding. The link between the Houston and Moscow control centers is a part of the control center network and undergoes continuous security analysis and protective upgrades. The Security Analysis and Response Team, a multilateral ground segment security team chartered by the ISS Program's Ground Segment Control Board, conducts this activity. This team initiated an analysis of the link between MCC-Houston and MCC-Moscow in 1999, and is scheduled to be completed in July 2000.



## Finding #14

NASA has initiated an agency-wide program to deal with general computer security. Significant parts of NASA's initial plan depend upon the voluntary compliance of system users including contractors.

## Recommendation #14

Expand the agency-wide security system development work to include less dependence on human compliance with the system. NASA should also require contractors to participate in its security efforts.

## Response

NASA concurs with both parts of the recommendation. Regarding less dependence on human compliance, all NASA Centers have installed software and hardware tools that automatically scan for hostile code, system vulnerabilities, and hostile intrusions. These tools are not perfect; they require human oversight. However, they do reduce the amount of manual labor and the amount of human discretion involved in finding and dealing with attacks. NASA is exploring with vendors the possibility of applying artificial intelligence techniques to identify patterns in intrusion detection data that may not be obvious. This field has not yet matured to the point that products or services are available, but we are hopeful that, in a year or two, prototype products may be available for evaluation. These products would reduce the amount of manual analysis required to identify attacks, and they would make it easier to correlate data from different Centers.

We also use audits and metric reports to verify that human compliance has been adequate. For example, this year we will engage a third party to perform a technical audit of IT security provisions at three NASA Centers. Metric reports on security plans, training, and system vulnerabilities help us to track performance, thereby reducing discretion in compliance with NASA policy.

However, IT security evolves rapidly. New threats must be countered manually until they are well enough understood for defense to be automated. Thus, we expect to rely on human intellect and energy to identify and deal with novel developments.

Regarding requiring contractors to participate in its security efforts, we issued for comments, in January, a draft regulation to be included in the NASA supplement to the Federal Acquisition Regulations. This regulation would require NASA contractors, who operate computers or network systems on behalf of NASA, to adhere to appropriate provisions of NASA policies and procedures for information technology security. Comments on this draft have been dispositioned, and we expect the final regulation to be issued shortly. Also we are including contractors, such as the

Consolidated Space Operations Contract, the Outsourcing Desktop Initiative for NASA, and the USA vendors, in various fora that coordinate IT security across systems operated on behalf of NASA. Although this effort is recent, we are seeing good cooperation. We expect integration of contractors to help maintain a seamless NASA IT security posture.

## Finding #15

Further analysis of NASA's planned agency-wide computer security system is needed to understand its vulnerabilities and the programs and activities to which the system should be applicable.

## Recommendation #15

Conduct a thorough analysis, together with the National Security Agency, to determine the level of computer security required by the Agency, the level of security that can be expected from the system and its most serious vulnerabilities. Also require all major mission or safety critical programs to have a qualified third party conduct a computer vulnerability analysis of their designs as soon as possible.

## Response

NASA concurs in principle with both parts of this recommendation. Regarding analysis with the National Security Agency (NSA), we conducted a thorough internal study in 1998 to determine the level of required computer security, and GAO audited our computer security the same year. In addition, we are using a combination of internal audits/tests and third-party audits/tests to determine our security at a technical level. Our metrics also provides ongoing information about the adequacy of our computer security. Finally, the NASA Inspector General has made computer security a high priority for audits and inspections. Thus, we are not sure that adding another layer of analysis by the NSA will add commensurate value. Every analysis or audit disturbs ongoing work, and, at some point, additional analyses can actually degrade security because they have negative marginal value. We will discuss with the NSA what services that they could provide, to establish whether contracting with them would add significant value above what is already underway.

Regarding major mission systems, we believe that there is merit in the recommendation but wish to consult with owners of such systems before levying this requirement. We require that managers of all "special management attention" systems complete IT security plans and provide written authorization to operate those systems this fiscal year. We expect that all major mission or safety critical systems are included among the special management attention systems. Thus, these activities will provide a documented baseline for discussion regarding the value of third-party analyses.

## Finding #16

NASA has established an Avionics Upgrade Architecture Team (AUAT) charged with studying Space Shuttle avionics systems and recommending upgrades. The AUAT has conducted a thorough study and developed an excellent Block I upgrade plan that addresses the most serious needs, but as yet it is unfunded.

## Recommendation #16

Proceed with full funding for the proposed Block I Space Shuttle avionics upgrades as rapidly as possible.

## Response

The SSP has two categories of avionics upgrades - safety and supportability. Both safety upgrades and hardware supportability upgrades meet the Agency's goal of continued and reliable Shuttle operations, with significantly reduced safety risks, through at least FY 2012.

NASA is aggressively developing an Upgrade Program Plan for implementing the safety upgrades into the Shuttle fleet by FY 2005. These upgrades include the avionics changes required to add cockpit displays for abort situation awareness, and enhanced caution and warning, which will provide information and solutions that will significantly reduce the crew workload for complex and/or multiple failures. Funding for the formulation phase (requirement definition and validation, design architecture, and subsystem procurement specification) for these upgrades has been authorized by the program and is underway. The current NASA SSP budget submission also provides for implementation funding.

Potential avionics supportability upgrades needed to reliably ensure that flight-certified hardware is available to support the Shuttle manifest through FY 2012 are under review. Ongoing avionics supportability upgrade analyses focus primarily on maintenance concerns associated with the orbiter integrated communications system. The case for upgrading the communications system, and the various upgrade options studied by the avionics supportability assessment team will be reviewed by the program during the POP 2000 planning cycle.

## Finding #17

Part of the AUAT's initial approach is to install three mission computers to augment the existing General Purpose Computers (GPCs). The specific functions to be off-loaded from the GPCs to the mission computers have yet to be determined. Eventually, the AUAT plans to consider moving some "Crit 1" functions to the mission computers.

## Recommendation #17

Do not move any "Crit 1" functions to the mission computers unless memory requirements in the GPC demand it and then only after an appropriate risk analysis is performed.

## Response

The avionics upgrade architecture has changed substantially since the ASAP visit early in 1999 when it contained both safety enhancements and supportability solutions. The currently funded content for the avionics upgrade addresses only the safety enhancements. These enhancements address upgrades to the crew cockpit to reduce crew workload and enhance safety margins relative to critical crew procedures. The focus has been on improving crew situational awareness through access to all vehicle data, more robust command capability from the keyboards and more computational power to perform higher-level functions (such as enhanced caution and warning and abort region determination) than previously supported. The result is an architecture that replaces the existing multi-functional electronic display system integrated display processor with a new computer, called the command and data processor, rather than incorporating a mission computer. The functions, such as crew commands and enhanced caution and warning that are now supported by the avionics architecture, are considered Crit 1 and will be certified to Crit 1 levels. The new processor has many of the attributes of the mission computer concept presented to the ASAP, including support for an aerospace ground equipment interface for flight computer data access.

## Finding #18

The long-term support of the International Partners with respect to software source code is essential to the safe operation of the ISS and the resolution of any software-related anomalies.

## Recommendation #18

Solidify long-term source code maintenance and incident investigation agreements for all software being developed by the International Partners as quickly as possible, and develop contingency plans for all operations that cannot be adequately placed under NASA's control.

## Response

The International Partners have all agreed to provide sustaining engineering support for their software throughout the life of the ISS, and the ISS Program will add this agreement to the multilateral ISSP Software Management Plan. In addition, NASA has established contingency plans for dealing with the loss of critical partner assets.

## AEROSPACE TECHNOLOGY

### Finding #19

Programs such as the non-defunct High Speed Research and Advanced Subsonic Technology often yield aircraft safety improvements. Elimination of these programs may well be inimical to advances in aviation safety.

### Recommendation #19

Identify those elements of the eliminated programs which had the potential to improve aviation safety and cover them elsewhere.

### Response

NASA concurs with this recommendation. NASA has retained the elements in the High Speed Research and Advanced Subsonic Technology program that have a potential to improve aviation safety. For example, a major element of HSR was the external vision system that was being developed to allow pilots to see forward without drooping the nose of a high-speed civil transport. This technology, being developed in HSR for clear weather applications, was transferred to the Synthetic Vision project in the Aviation Safety program. The technology will be developed to enable all-weather applications.

Additionally, two projects of the Advanced Subsonic Technology program were transferred to the Aviation Systems Capacity program. They are Terminal Area Productivity (TAP) and Advanced Transportation Technology (AATT). TAP is developing technologies to demonstrate safe, clear weather capacity during instrument weather conditions. AATT is developing technology to enable substantial increases in the effectiveness, efficiency, capacity, flexibility, predictability, and safety of the national and global air transportation system.

## Finding #20

The involvement of Center Directors in aviation flight readiness, flight clearance, and aviation safety review board matters is not uniformly satisfactory.

## Recommendation #20

Underscore the need for Center Directors to become involved personally in aviation flight readiness, flight clearance, and aviation safety review board matters.

## Response

Each Center that operates aircraft for research or program support has established and maintains an airworthiness and flight safety review process board consistent with the level of aircraft modification activity which takes place at the Center. Additionally a requirement exists that every NASA Aviation Safety Officer have a formally established direct line of communication with the Center Director. These processes and their implementation are inspected at each biennial Intercenter Aircraft Operations Panel (IAOP) Review of the Center's flight operations activities. The Center Director is debriefed at the end of each review. The IAOP will increase the emphasis on the need for the Center Director to remain personally involved in airworthiness and aviation safety matters.



## Finding #21

NASA's responsibilities with regard to aviation flight safety when a contractor conducts flights and/or provides payloads are not clearly defined.

## Recommendation #21

Define more explicitly the safety responsibilities of NASA Centers when conducting, supervising, or participating in contractor-operated aviation flight and payload operations.

## Response

NASA's responsibilities concerning the conduct of contract flight operations have been clearly defined in an Office of Management Systems Interim Policy Letter, dated 7 Jun 99, which establishes responsibilities and actions required when non-NASA aircraft are used to support NASA research requirements. This interim policy has been entered into the formal NASA Policy and Guideline system. The policy places the responsibility for review of all contracts, flight operations plans, and supervision of those activities directly with the Center's Flight Operations Office. If the Center has no such office, the NASA Headquarters Aircraft Management Office, in conjunction with the appropriate Enterprise, will assign the responsibility to the most suitable NASA Flight Operations Office.

## Finding #22

The chain of safety responsibility for the operation of the Stratospheric Observatory for Infrared Astronomy (SOFIA) aircraft is complex and unclear.

## Recommendation #22

Sort out and clear up the SOFIA chain of flight operations safety responsibility.

## Response

The chain of flight operations safety responsibility of SOFIA is as follows: Within NASA, the Center Director at the Ames Research Center (ARC), the designated Lead Center for SOFIA, has the responsibility to ensure the safety of SOFIA, including flight operations. The Center Director has a Safety and Mission Assurance (S&MA) Office, which ensures that Agency policies for safety are followed, as well as an Airworthiness and Flight Safety Review Board (AFSRB), which provides specific oversight for aircraft airworthiness. These two mechanisms for safety oversight report directly to the Center Director and work closely and regularly with the SOFIA Program Office at ARC, which directs the SOFIA contractor team. An experienced NASA Flight Operations Manager for SOFIA carries the responsibility within the SOFIA Program Office to ensure that safety of flight operations receives the utmost attention in contractor activities.

Further details follow, starting from the lowest level to show the foundation of flight operations safety embodied in the SOFIA program wherein aircraft operations will be performed by United Airlines (UAL).

The first level of aircraft operational safety responsibility, working from the bottom-up, is that SOFIA aircraft operations and maintenance will be accomplished by UAL, the SOFIA contractor for aircraft operations, under UAL Operations/Specifications, which meet or exceed the operations rules established by appropriate Federal Aviation Regulations (FAR), Airworthiness Directives, and Service Bulletins. The program will be overseen and certified by the FAA for FAR compliance. Appropriate clearance and signoffs, as mandated by UAL Operations/Specifications, will be the responsibility of UAL.

NASA policy also requires effective NASA oversight for safety. This is accomplished by NASA's Ames Research Center (ARC) as the designated Lead Center within NASA for SOFIA. At ARC, as with programs at other NASA Centers, the Center Director delegates overall program management for SOFIA to the SOFIA Program Manager, reporting directly to the Center Director to ensure visibility.

Directly supporting the SOFIA Program Manager is the NASA Flight Operations Manager for SOFIA, experienced in aircraft flight operations and

qualified to make routine SOFIA flight operations approval decisions. This individual, a senior experienced operations expert and pilot, also has the current responsibility for ensuring that that appropriate expertise in flight operations and flight safety is incorporated into the current design and development of SOFIA and into the planning for SOFIA flight operations.

In addition, to ensure matters of safety and airworthiness receive the utmost attention and visibility, the ARC Center Director has in place two other mechanisms. First, there is an independent Safety and Mission Assurance (S&MA) Office at ARC that works closely with the SOFIA Program Office, but reports directly to the Center Director and has direct ties to the NASA Headquarters S&MA Office to ensure overall Agency policy on safety is followed. This ARC S&MA Office has direct and on-going access to the ground and flight operations activities of the SOFIA contractor team.

Second, the ARC Airworthiness and Flight Safety Review Board (AFSRB) provides airworthiness oversight for SOFIA aircraft modifications and mission equipment installations. The AFSRB reviews the SOFIA aircraft design, related technical analysis, development testing and all associated documentation, and provides airworthiness recommendations to the Center Director for conduct of test flights, for initiating routine flight operations, and for reinitiating flight operations following any subsequent, significant aircraft modifications.

Concurrence in the approval of development and checkout flights will be required from both the AFSRB and the Head of the ARC S&MA Office.

Safety oversight as structured above by ARC management was previously agreed to by the NASA Headquarters Office of Management Systems (Code J), with the cognizance and concurrence of the NASA Headquarters Offices of Space Science (Code S) and S&MA (Code Q).

In a more recent organizational change prompted by an internal NASA review, ARC is establishing an Aviation Management Office to have certain management responsibilities for all aircraft operations at ARC, recognizing that two non-NASA organizations (U.S. Army and U.S. Forest Service) also conduct flight operations at ARC. The details of these responsibilities, and in particular their inter-relationship with the previously approved oversight structure for SOFIA outlined above, are under development at this time.

## Finding #23

In planning for SOFIA operations, aviation safety and flight personnel have had minimal involvement.

## Recommendation #23

Involve cognizant aviation safety and flight personnel in SOFIA planning and development on a routine basis.

## Response

The SOFIA Program has maintained involvement of aviation safety and flight personnel, from both NASA and UAL, from the beginning of development. However, to ensure that no potential problem areas are overlooked, the program has recently taken steps to increase the involvement of aviation safety and flight personnel.

The SOFIA prime contractor has elevated senior aviation operations experts into the operations planning process during the development phase. Also, additional senior aviation operations personnel at UAL, the major subcontractor assigned the role for aircraft operations, have been brought into the process and have had input into training and operations issues. Further, the level of inclusion of the NASA SOFIA Flight Operations Manager, a senior and experienced operations expert and pilot, concerning development and operations plans has also increased, as has the degree of communication on such matters with the NASA SOFIA Program and Project Managers.

SOFIA is approximately 2 1/2 years from the start of operational flights. If additional measures are determined to be necessary to ensure adequate involvement of aviation safety and flight personnel, for instance as the responsibilities and staffing of the newly created ARC Aviation Management Office are clarified, they will be implemented.

A further step that has been taken at NASA Headquarters is the establishment of a SOFIA External Independent Readiness Review (EIRR) Team by the Associate Administrator for Space Science. EIRRs are used by NASA to support the responsible Associate Administrator's oversight of approved programs, wherein a small team is formed of highly knowledgeable specialists from organizations external to the program, and in most cases, external to NASA. Although the scope of the SOFIA EIRR is intentionally broad to cover such program issues as science utility, engineering integration, and mission risk, a third of its membership represent detailed expertise in aircraft flight safety and operations, reliability and safety analysis, and modification and FAA certification. Although only in place since March of this year, their input has already proven valuable to the SOFIA program, and will continue to provide an additional check that proper attention is paid to operations and safety concerns.

## Finding #24

As currently configured, the SOFIA aircraft does not contain avionics consistent with best practices for international operations.

## Recommendation #24

Ensure that the SOFIA aircraft is configured in accordance with prevailing international airline avionics practices.

## Response

The SOFIA 747SP is outfitted with the avionics it had when it was built. These will be updated consistent with future air navigation requirements and UAL fleet plans. UAL is committed to operating SOFIA safely and efficiently as they do for all aircraft in their fleet. SOFIA will satisfy all Federal Aviation Regulations and ICAO requirements and will be operated under UAL Operations/Specifications. The critical elements of the cockpit avionics configuration, as well as plans for future upgrades, are undergoing final determination in preparation for the Critical Design Review.

## Appendix C

### AEROSPACE SAFETY ADVISORY PANEL ACTIVITIES

#### JANUARY-DECEMBER 2000

##### JANUARY

January 12–13, 2000 – League City, TX, NASA Research 2000 Leadership Summit

January 18–19, 2000 – Kennedy Space Center, STS-99 Flight Readiness Review

##### FEBRUARY

February 8–10, 2000 – NASA Headquarters, ASAP Annual Meeting

February 11, 2000 – Goddard Space Flight Center, Fact-Finding

February 22–25, 2000 – Johnson Space Center, Payload Safety Conference

February 28, 2000 – Johnson Space Center, USPM Safety TIM

February 29, 2000 – Johnson Space Center, Fact-Finding

##### MARCH

March 1–2, 2000 – Johnson Space Center, USPM Safety TIM

March 15–17, 2000 – Kennedy Space Center, Fact-Finding

March 21–22, 2000 – San Antonio, TX, Space Station Program Management Review

March 23, 2000 – NASA Headquarters, Panel Administration (Meet with Mr. Goldin) and SOFIA Briefing

##### APRIL

April 3–6, 2000 – Johnson Space Center, ICM TIM

April 4–5, 2000 – Kennedy Space Center, STS-101 Flight Readiness Review

April 4–6, 2000 – Johnson Space Center, ICM Safety TIM

April 22–25, 2000 – Kennedy Space Center, STS-101 Prelaunch Mission Management Team Review and Launch

April 25–27, 2000 – Huntington Beach, CA, Propulsion Module Delta Preliminary Design Review

## MAY

May 9, 2000 – Kennedy Space Center, Space Station Program Integrated Logistics Panel Meeting  
May 16–18, 2000 – Marshall Space Flight Center, Plenary Session

## JUNE

June 1, 2000 – West Palm Beach, FL, Pratt and Whitney, Fact-Finding  
June 6, 2000 – Palmdale, CA, The Boeing Company, Fact-Finding  
June 7, 2000 – Jet Propulsion Laboratory, Fact-Finding  
June 8, 2000 – El Segundo, CA, The Aerospace Corporation, Fact-Finding  
June 20–21, 2000 – Langley Research Center, Fact-Finding  
June 22, 2000 – NASA Headquarters, Meeting with Mr. Rothenberg, Mr. Hawes, and Mr. Holloway  
June 27–28, 2000 – Johnson Space Center, Computer Team Visit

## JULY

July 7, 2000 – Kennedy Space Center, USA Independent Assessment Team  
July 11, 2000 – NASA Headquarters, CRV PMC  
July 19–20, 2000 – Wallops Flight Facility, Fact-Finding  
July 25, 2000 – Ames Research Center, Fact-Finding  
July 31, 2000 – Kennedy Space Center, Fact-Finding

## AUGUST

August 1, 2000 – Kennedy Space Center, Fact-Finding  
August 2, 2000 – NASA Headquarters, CRV Meeting  
August 8–10, 2000 – Johnson Space Center, Plenary Session  
August 14, 2000 – NASA Headquarters, Fact-Finding  
August 14–17, 2000 – Waco, TX, Stratospheric Observatory for Infrared Astronomy Critical Design Review  
August 29, 2000 – Kennedy Space Center, STS-106 Flight Readiness Review

## SEPTEMBER

September 11–12, 2000 – Dryden Flight Research Center, Fact-Finding  
September 12, 2000 – West Palm Beach, FL, Pratt and Whitney, Alternate Fuel Turbopump DCR  
September 14, 2000 – NASA Headquarters, Fact-Finding  
September 21–22, 2000 – NASA Headquarters, Fact-Finding  
September 28, 2000 – Kennedy Space Center, STS-92 Flight Readiness Review  
September 29, 2000 – Kennedy Space Center, ISS Program Status, Development, and Operations Meeting

## OCTOBER

October 5–6, 2000 – Dryden Flight Research Center, Fact-Finding  
October 10–11, 2000 – Kennedy Space Center, Fact-Finding  
October 10–12, 2000 – Ames Research Center, Design for Safety Conference  
October 17, 2000 – Stennis Space Center, Fact-Finding  
October 18, 2000 – Michoud Assembly Facility, Fact-Finding  
October 25, 2000 – Kennedy Space Center, Logistics-Suppliers Conference  
October 30, 2000 – Johnson Space Center, Computer Security Debrief

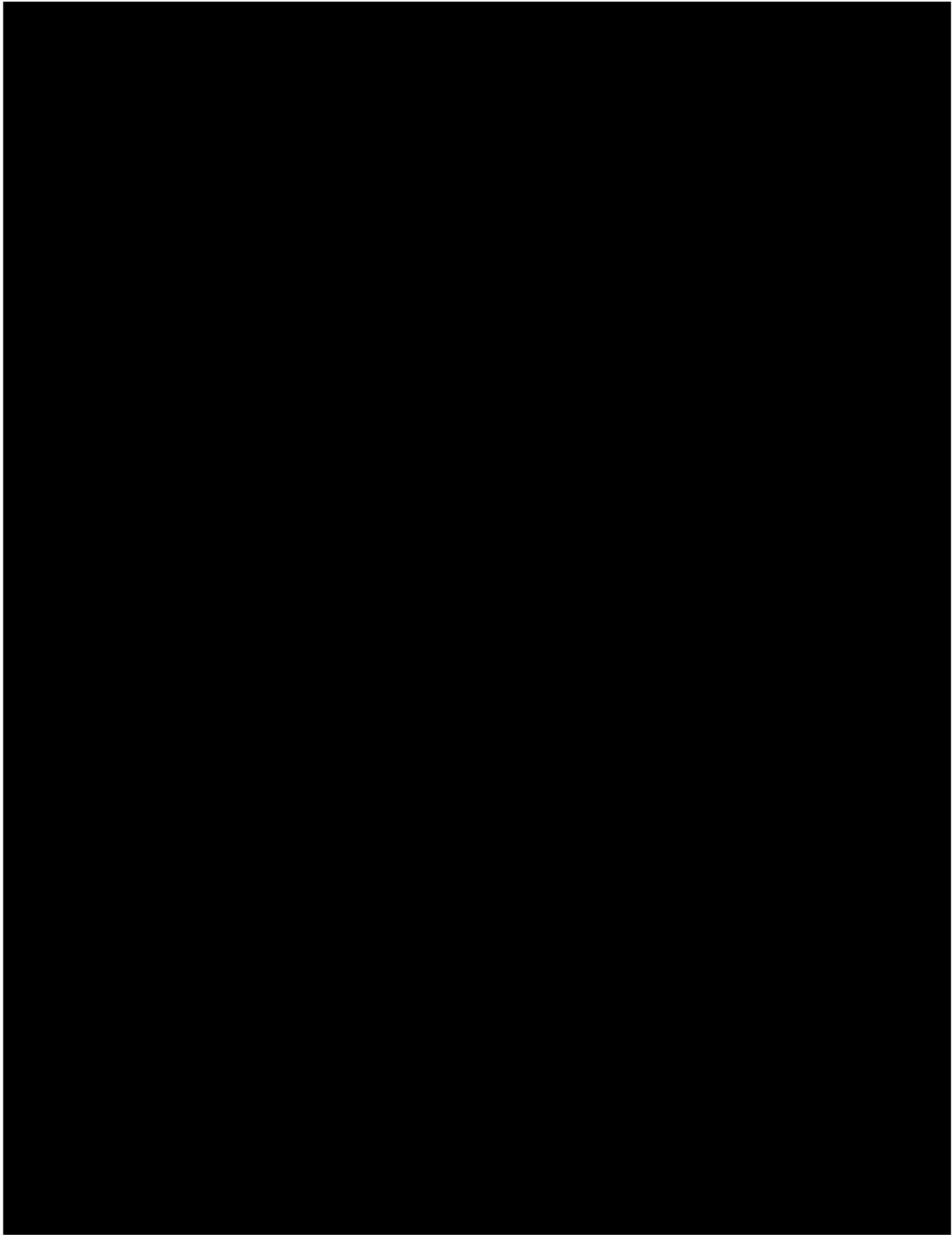
## NOVEMBER

November 8, 2000 – Johnson Space Center, Meeting with Mr. Holloway  
November 9–10, 2000 – NASA Headquarters, Plenary Session  
November 14, 2000 – Marshall Space Flight Center, Integrated Logistics Panel Meeting  
November 17, 2000 – Kennedy Space Center, STS-97 Flight Readiness Review  
November 20, 2000 – NASA Headquarters, Meeting with Mr. Goldin  
November 28, 2000 – NASA Headquarters, Meeting with Ms. Novak  
November 29–30, 2000 – NASA Headquarters, Editorial Committee Meeting  
November 29–30, 2000 – Boeing Huntington Beach, CA, Crew Escape System Final Concept Review  
November 29–30, 2000 – Goddard Space Flight Center, Software Engineering Workshop  
November 30, 2000 – Kennedy Space Center, Final Briefing of USA Independent Assessment Team

## DECEMBER

December 13, 2000 – NASA Headquarters and Telecon, Editorial Committee Meeting







National Aeronautics  
and Space Administration

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